Guidebook to Field Tours of the

# 2009 National Cooperative Soil Survey Conference

# Welcome To New Mexico

I am very pleased New Mexico was chosen to host the 2009 Conference of the National Cooperative Soil Survey in New Mexico.

The Soil Survey has always been an important tool in our efforts to conserve soil, water and other natural resources. New Mexico participated in the earliest days of the Soil Survey Program undertaking a survey of the Pecos Valley in 1898 - fourteen years before its statehood. Soil Surveys are important because it is upon the soil that we plant our crops, grow our livestock, and raise our families.

New Mexico truly is the *"Land of Enchantment"*. It is a state rich in diversity of landscapes, climate, natural resources, and people. We appreciate this chance to share a bit or our lives in the land we call home. During your stay here, please take the opportunity to visit some of the scenic beauty and cultural offerings of the state. If in a restaurant and asked the question, "Red or Green?" simply reply "Christmas". They will smile and know what you mean.

Cooperative partnerships are essential to success in resource management in New Mexico. Challenges posed by complex patterns of land ownership, limited water resources, and diverse cultures are best answered when we work together. The National Cooperative Soil Survey is one of our oldest and most dynamic cooperative efforts to help us protect and enhance our natural resources.

DENNIS L. ALEXANDER
STATE CONSERVATIONIST

*Crescit Eundo* – "It Grows As It Goes" – New Mexico

# Contents

**Overview of Tours**



**Sunday, May 10, 2009 -7:30AM-5:30PM**



**Tuesday, May 12, 2009 – 7:30AM-8:30PM**



**Wednesday, May 13, 2009 – 1:00PM-5:00PM**

# The 2009 NCSS Conference Tours

We are pleased to be able to schedule three tours for the 2009 National Cooperative Soil Survey Conference in Las Cruces, NM. The tours are designed to highlight the soil survey process from beginning to end emphasizing the contributions of partners in development of a complete product for the users.

The Sunday tour of the White Sands Missile Range begins with the broad view of the geologic, geomorphic and climatic setting in which soil surveys are conducted and soils products developed. We will be looking at the parent materials and the processes which have brought them to the land surface where soil forming processes have acted upon them over the millennia to shape and alter parent material into soils we map. We will look primarily at tectonic, geomorphic and hydrologic processes which redistribute the raw materials across the landscape and act to alter their composition.

The Tuesday tour of the Jornada Experimental Range and LTER consists of three mini-workshops. Workshop 1 will highlight soil-geomorphic relationships developed during Desert Soil-Geomorphology Project conducted from 1957-1972, but study continues today with additional research, synthesis of ideas, and extrapolation of concepts across additional landscapes and geologic settings using the latest analytical techniques and climate modeling. Workshop 2 will present the techniques of Ecological Site Description and State and Transition Model development developed through collaborative efforts of the USDA Jornada Experiment Station, New Mexico State University and other researchers to identify the stable plant communities in the Chihuahuan Desert, and the changes in state and the transition thresholds brought about by disturbance. Workshop 3 is a demonstration of multi-scale field methods to document the effects of management and disturbances on dynamic soil properties according to the newly released interagency Soil Change Guide: Procedures for Soil Survey and Resource Inventory.

The Wednesday afternoon Agronomy Tour at the Anthony Pecan Farm consists of four demonstration or discussion stations which emphasize management of soil health and long term sustainability. Processes used include the inventory for status of dynamic soil quality parameters; analysis of crops for nutrient uptake, analysis of irrigation water chemistry, and organic nutrient inputs for the development of management plans which optimize yields, maximize irrigation efficiency, and reduce deleterious impacts to water quality, and all the while maintaining soil health for long term sustainability. The stations include an overview of soil health, discussion of crop, soil, and water analysis, demonstration of the Soil Quality Test Kit, and discussion of maximizing irrigation efficiency through proper selection of irrigation systems, soil moisture monitoring, and irrigation water management.

# General Precautions and Considerations

**Exposure --You are in a desert!**

The climate in the Chihuahuan Desert can be dangerous if you are not aware of or prepared for it. Your body may not be acclimated to the combination of altitude, low humidity, and high temperatures. You may not feel the effects of sun exposure, dehydration, and altitude until you are already in serious medical trouble. Please follow these easy safety tips to assure your continued enjoyment of New Mexico:

* Drink plenty of water – drink frequently and before you become thirsty - approximately 1 gallon per day in summer
* Minimize sun exposure on bare skin – wear a wide brimmed hat, long sleeve shirt, long pants, lightweight, loose fitting clothing, and durable protective footwear; use sunscreen lotions of SPF 30 or stronger
* Eat frequent light meals – avoid greasy and high protein foods
* Take a siesta – rest frequently, retreat to shade, and avoid strenuous activity in the heat of the day
* Avoid alcohol and caffeine which dehydrate the body
* Inform someone if you suddenly become dizzy or ill

**Flora and Fauna**

Many species of plant and animal in the desert utilize protective systems to deter predation, including thorns, spines, fangs, and stingers. Watch where you step and what you brush up against. Succulent plants and tender leaves are always protected by spines and thorns. Snakes, spiders, and stinging insects take protection in shady areas under rocks, limbs, and structures.

**White Sands Missile Range- UXO and Photography**

White Sands Missile Range is a secure military facility used for weapons testing since 1945. The weapons tested are designed to kill the enemy and destroy machinery and are very effective at both. Precautions have been take to avoid known ordinance testing areas, but accidents and misplaced explosives can be found anywhere on the range. Do not pick up, step on, or go near anything that looks suspicious. Report any sighting to the tour leader. Please watch the UXO briefing video at http://www.wsmr.army.mil/videos/uxo-brief.wmv .

For the purposes of national security, no unauthorized photography is permitted. You risk seizure of equipment and imprisonment for violation. Even photos taken by authorized personnel are screened by military security personnel.

**Jornada Experimental Range (JER)**

The Jornada Experimental Range and Long Term Ecological Research Station is an active research facility with numerous experimental plots, sensor packs, data loggers, and livestock. Please be wary to avoid damage to experiments, and angering ruminate megafauna.

**Agronomy Tour - Anthony Pecan Farm**

The Diaz Family has graciously hosted numerous workshops, demonstrations, and training exercises for NRCS on their Anthony pecan farm. We value their friendship and support.

# White Sands Missile Range Tour

## May 10, 2009

# 2009 NCSS National Conference
# White Sands Missile Range Tour Itinerary
# Sunday, May 10, 2009

## Tour Departure

Location: Corbett Center, New Mexico State University

Estimated Time of Departure: 7:15 AM

Travel Time to First Stop: 7:15 – 7:55 AM

Purpose:
- Brief summary of day's events
- Photography restrictions
- Load NCSS tour group onto buses

## Stop 1

Location: San Augustine Pass, Dona Ana County, NM

Estimated Time at Location: 7:55 – 9:00 AM

Travel Time to Second Stop: 9:00 – 10:15 AM

Purpose:
- Unexploded Ordinance and Photography briefing
- History of White Sands Missile Range
- Geologic History and Formation of the Tularosa Basin
- Soils, Temperature and Moisture Regimes and Ecological sites from pass to basin floor
- Landforms at Stop 1

Enter White Sands Missile Range at Small Missile Range gate at 9:20 AM

## Stop 2

Location: Selenite Banks, Sierra County, NM, White Sands Missile Range

o

- Display of pedogenic gypsum samples and other gypsum precipitates
- Soils and Ecosites of piedmont and northern Alkali Flat
- Landforms at Stop 2

## Stop 3

Location: White Sands Missile Range Dune Field, Otero County, NM,

Estimated Time at Location: 12:00 – 1:30 PM

Travel Time to Fourth Stop: 1:30 – 1:40 PM

Purpose:

- Lunch
- Dune Types
- Water table influence on Dune Formation
- Soils and Ecosites of Dune Field
- Munsell White Page
- Landforms at Stop 3

## Stop 4

Location: White Sands Missile Range Alkali Flat, Otero County, NM,

Estimated Time at Location: 1:40 – 2:40 PM

Travel Time to Fourth Stop: 2:40 – 3:40 PM

Purpose:

- Deflation Events on the Alkali Flat
- Ground Water and Salinity
- Gypsum Interps in Open and Closed Basins
- Soils and Ecosites of Alkali Flat
- Landforms at Stop 3

## Stop 5

Location: Fault Scarp, Dona Ana County, NM,

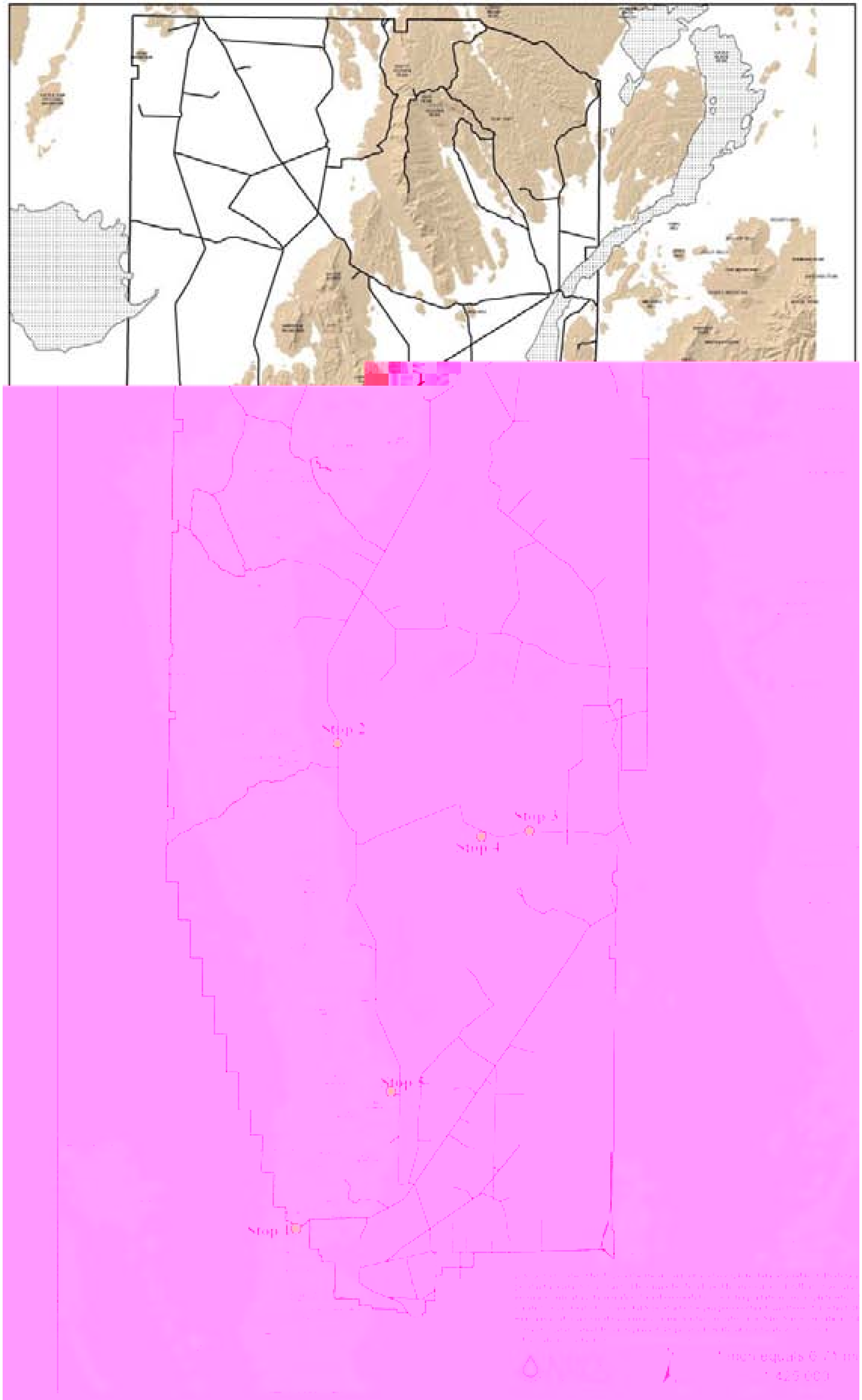
Estimated Time at Location: 3:40 – 4:40 PM

Travel Time to Corbett Center: 4:40 – 6:00 PM

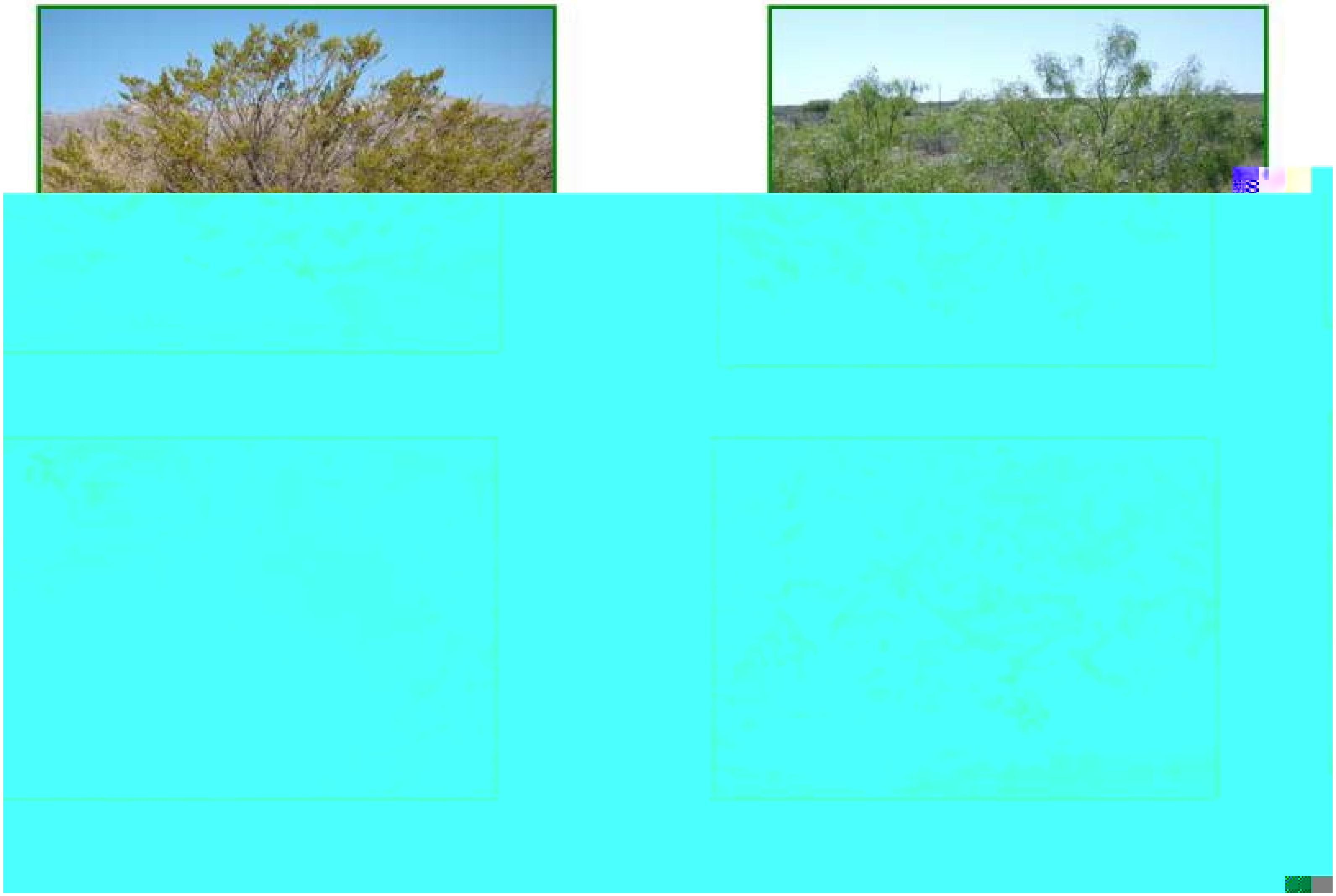
Purpose:

- Discuss Fault Systems in Tularosa Basin
- Soils and Ecosites of Piedmont and Fault Scarps
- Landforms at Stop 5

Leave White Sands Missile Range at Small Missile Range gate at 5:10 PM


Stop 2
Stop 3
Stop 4
Stop 5
Stop 1

# Piedmont Vegetation

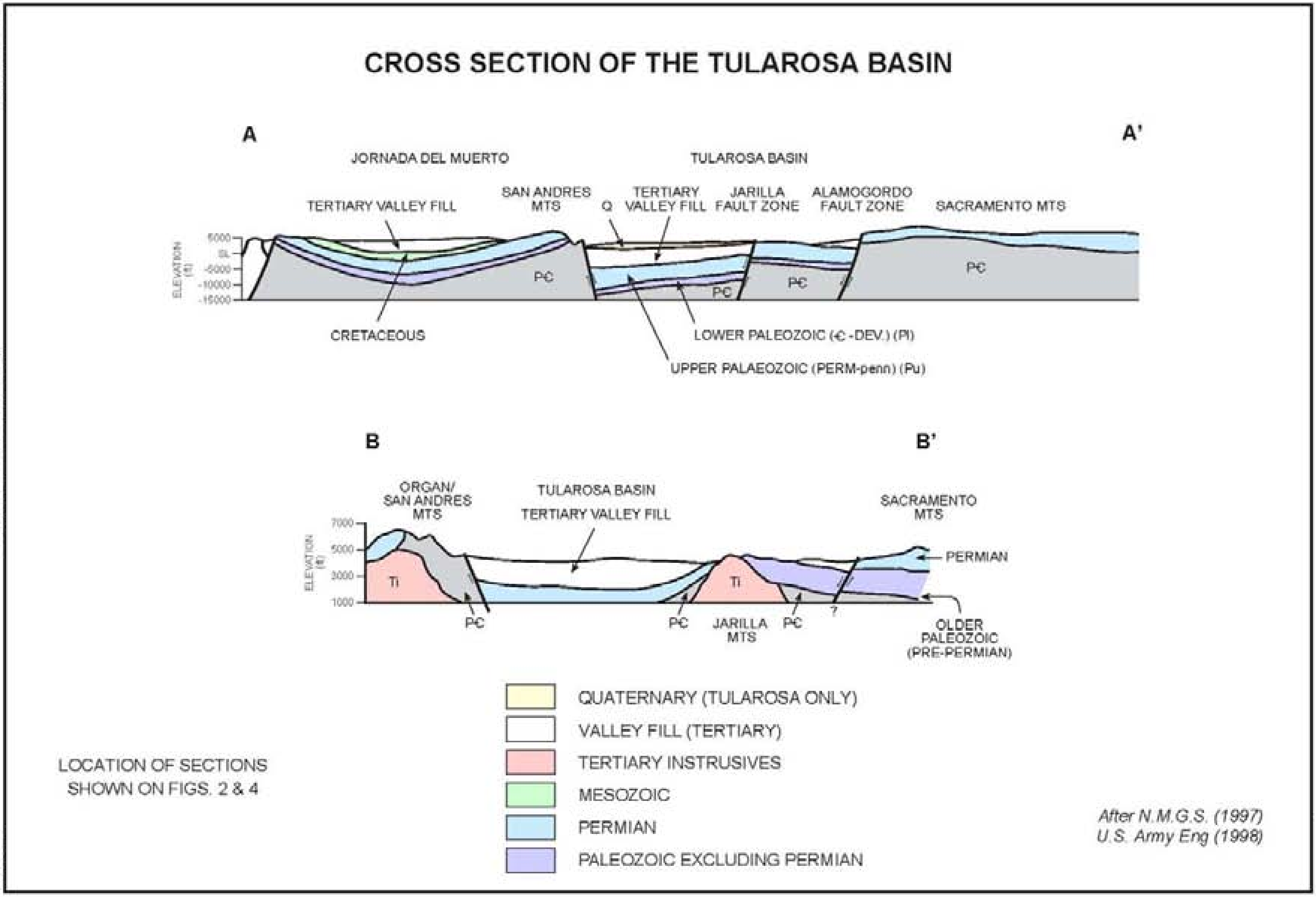


# TULAROSA, OTERO COUNTY, NEW MEXICO

Weather station **TULAROSA** is at about 33.10°N 106.00°W. Height about 1388m / 4554 feet above sea level. **Source:** TULAROSA data derived from GHCN 1. 966 months between 1908 and 1989

## Average Rainfall

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | 12.9 | 12.3 | 11.3 | 9.2 | 12.0 | 18.5 | 40.8 | 43.4 | 37.6 | 22.7 | 12.9 | 16.3 | 250.5 |




Drawn by UESG01

Shell U.K. Exploration and Production
August 1999

CDO.94818

Figure 1-3

# Geology of White Sands

## Chapter 4: Dune Systems

http://www.nps.gov/archive/whsa/Geology%20of%20White%20Sands/Chap04/Chap04%20Main.html

## Introduction:

White Sands has many features in common with other dune fields around the world. In addition to a similarity of process and product due to the importance of wind in shaping the landscape, it also consists of a number of terrain types common to all eolian systems. The dune facies encompasses of all the myriad types of dunes found around the White Sands. The interdune sediments are deposited in the sheltered areas between dunes. Interdune sediments have very different sedimentary features than dunes, and process regimes are so different from those of nearby dunes, that they have been recognized separately by geologists; even though they evolve interdependently surrounding dunes. The third important eolian sediment group is sand sheets. These are widespread, flat-bedded deposits that are commonly found at the margins of many dunefields. The fourth sediment group, which is also found at White Sands is the eolian sabkha. Eolian sabkha deposits form when dry sand is blown across damp surfaces near water table, particularly in evaporitic settings such as White Sands. Sabkha deposits are common on the alkali flat and on the margins of Lake Lucero, and are also found in some open places within the dunefield. In addition there are important terrain types at the White Sands that are not formed by wind - for example the **playa** sediments of Lake Lucero and **fluviatile** sediments of streams that onto the playa and into the dune field. Additionally, there are striking erosional terrains around the monument that testify to the forward movement of dunes or even the removal of significant portions of the landscape by wind scour. Our method in the next series of chapters is to discuss these basic terrain types one by one, after reviewing certain basic aspects of sand and dune movement, and the gypsum sand. We hope to provide some facts about the origins and growth, internal architecture, sedimentary features and current process regimes of the various terrains of the White Sands.

## Sand movement

Sand movement by wind is a complex process involving several styles of grain movement by wind that occur more or less simultaneously (Bagnold, 1941). The process most easily observed is saltation, the bouncing of sand grains near the sand surface, sometimes in streamers. A second component of the sand drift process is surface creep. Surface creep is the jerky forward movement of larger grains that are too heavy to be lofted by the wind, but are jolted forward when struck by smaller flying grains. The third manner in which smaller sizes of sand moves is by suspension. Suspended grains are so small that they are carried along without returning to the ground once they are thrown into the air by saltating grains or direct wind scour. Some of the suspension population is merely dust, which is carried far into the atmosphere and far away from the dunes. One of the reasons dune sand is so well sorted is the narrow size range of sand that wind can move under most conditions - usually grains up to .5 mm or so in size. Larger grains are too heavy to be moved by wind and are soon left behind, the silt and clay size fractions are either removed to the atmosphere or settle into sheltered places such interdunes.

# Dune Growth and movement.

Dune growth and movement is a result of sand flow on and around a dune during periods when the wind is strong enough to move sand (for dry sand this threshold is about 15 mph). Dunes are constantly changing shape in response to changes in wind velocity or direction. Dunes grow when more sand drifts onto them from surrounding areas than is removed downwind. During storms, sand flows over all parts of the dune. Sand that flows over the center parts of the dune settles on the upper part of the slipface as grainfall deposits formed by settling in the lee of the dune. When the sand accumulates to a certain thickness or angle (the angle of repose: about 32 degrees) it becomes unstable and slides down the slipface. This process, known as avalanching is the basic mechanism of forward advance of most of the bedforms at the Monument. It is clear that some sand that drifts on to the dune from upwind can move past this dune and not become trapped in the slipface. Thus, this dune lives in a continual balance between sand loss at the arms and sand entrapment on the slipface.

One curious aspect of dune growth concerns the relationship of the slipface to the windward slope of the dune. T the highest point on the dune is not at the top of the slipface, but upwind, on the dune crest. Clearly, in this bedform, the dune crest deposits, which consist of ripple strata have grown higher than the slipface. Thus, part of the key to the upward growth of this bedform may lie in the ability of the ripples on the top of this dune to trap oncoming sand, as well as in the ability of the slipface to store it.

# Origin and nature of the gypsum sand

White Sands is extraordinary in that most of the eolian deposits are composed almost entirely of gypsum sand. The geologic origins of this sand are discussed in Chapters 1 and 2, but it is useful to briefly review here the physical nature of the sand and it's proximal sources.

Generally speaking, average sand sizes grow finer from upwind (near lake Lucero) to downwind across the Monument. The fining of sand downwind reflects the breakdown of the gypsum crystals through weathering as well as rounding and breakage to smaller sizes through saltation impact.

Gypsum, with a specific gravity of 2.32 g/cm3 is slightly less dense that quartz, which has a specific gravity of 2.65 g/cm3. Despite this difference, which makes gypsum slightly easier than quartz for the wind to move, we could find no major difference between the behaviour of gypsum and quartz either in habit of transport by wind, or in the way in which dunes are formed. One significant difference does become evident after sand is deposited, however. Because gypsum is much more soluble in water than quartz, early cementation of the dune and other sands at White Sands is widespread. This occurs in two main ways; (1) solution by rainfall, followed by drying (light meniscus cement between grains) or precipitation due to evaporation at the top of the capillary fringe (heavy, pervasive cement) (Schenk and Fryberger, 1988). This may slow dune migration rates, or perhaps change the shapes of dunes slightly due to resistance to scour of windward slopes. It may also affect rates of eolian down cutting of source areas to feed new sand to the dunefield. However, the similarity between the eolian deposits and processes at White Sands and other dunefields formed mainly from quartz is quite striking, in the author's experience, while differences are subtle.

The present study as well as those of Almendinger (1971) and Almendinger and Titus (1973) indicates that the primary source of sand for the dune field both in past and present is re-cycling of gypsum crystals from deposits of Pleistocene Lake Otero. Secondary sources include recycling of sand from older dunes and much smaller quantities of freshly precipitated gypsum formed by precipitation from the shallow groundwater table.

# Dune types at the Monument

Most of the freely moving dunes at the Monument are of the **barchanoid** type that develops a major slipface transverse to a single dominant wind direction and moves in that direction - which is from the southwest at White Sands. Barchanoid dunes are one of the several major classes of dune morphology known to exist generally. Two other important types are known as linear dunes (elongate dunes that form in parallel rows) and star dunes (star shaped in plan view) are not known to exist at White Sands. Linear dunes develop in bimodal wind regimes, and star dunes in complex, multidirectional wind regimes (Please see Schenk, 1990, for a very readable summary of dune forms and wind regime from a worldwide perspective, and Chapter 9 for summary of dune forms and wind regime). Although the wind regime at White Sands is not perfectly unimodal, the winds sufficiently dominated by the single southwest mode that barchanoid forms dominate the landscape.

Sand roses that summarize effective wind directions through the year for White Sands, based on wind data from Holloman Air Force Base located at the eastern boundary of the Monument. These roses illustrate that the strongest and most common winds are from the southwest, although there are significant flows from the north-northwest and southeast as well at various seasons of the year. There are a number of subtypes of the barchanoid family present at White Sands including barchans, barchanoid ridge and transverse ridge dunes (McKee, 1966). Barchan dunes have curved slipfaces and two horns extending downwind, with proportions in plan view much like a horseshoe. Barchanoid ridge dunes have a longer slipfaces that are sinusoidal in plan view, thus forming a more laterally continuous bedform. Transverse ridge dunes have slipfaces that are relatively straight and continuous. All these types migrate downwind through the erosion of the windward slope deposits and deposition on avalanche faces and lateral horns or extensions.

Another type of dune which has transverse affinities is the **dome dune**. Dome dunes, however, have no slipfaces most of the time. They have long been considered embryonic forms, that evolve downwind into barchanoid types with slipfaces; and indeed are found most commonly at the upwind margins of active dune field.

In addition to freely moving dunes, White Sands also has many tracts of dunes partially anchored by vegetation. **Parabolic dunes** have an actively migrating central mass and long arms that extend upwind, as opposed to shorter arms of the barchan that extend downwind. Also, there are much smaller dunes that do not move called **coppice dunes** that represent sand accumulating within and around small shrubs or grass. Usually, when the plant dies, the sand blows away and may or may not survive as a dune. Another unusual dune type at White Sands is the **lunette dune**, so named because of its shape when associated with small lakes. Lunette dunes form in the lee of lakes, and assume the shape of the shoreline, which is the immediate source of sand for construction of this immobile bedform. Of course, if the shoreline is not roughly circular in shape lunette dunes can grow quite elongate, however the shape is quite distinctive. They often in a semi-arid setting, and are commonly partially vegetated. Most of the lunettes at White Sands appear to be older than the present active dune field, and have been somewhat reduced by weathering. However, they are easily visible on aerial photographs. These dunes seem to be non-migratory, perhaps due to stabilization by vegetation.

# Sedimentary features of the dunes

The principal small-scale sedimentary features of the dunes include various kinds of primary and secondary laminations and bedding, as well as an internal structure reflecting growth, then partial erosion followed by renewed growth. The most common small-scale features are known as **primary stratification**. The two most common primary eolian stratification types are **avalanche** and **ripple** strata. Avalanche strata are formed when sand slides down the slipface of the dune after accumulating at the top and over-steepening past the natural angle of repose for dry sand. These strata are often an inch or more in thickness and rather massive, with drag structures that give evidence of shearing. Sometimes they are inversely graded due to rise of finer grains through the turbulent mass of sand that is sliding downhill. If the sand is damp at the time of avalanching, blocks of cohesive damp sand may be seen in trenches or on the slipface. Ripple strata are formed as one ripple migrates over another, preserving part of the ripple in front of it. Ripple strata are nearly always expressed as fine, thin laminations that are rather straight. Each thin ripple stratum is separated from the next by a thin layer of fines that accumulated in the trough of the ripple. These thin strata are known as pin-stripe laminations and are quite distinctive of eolian deposits.

The internal stratification of the dunes at White Sands was studied by McKee (1977) in a classic study that has been used worldwide by students of sand dunes. The light cementation typical of the gypsum dunes in the main dune mass made it possible for U.S Army, who helped McKee on this project, to bulldoze clean, flat cuts in several directions that revealed in extraordinarily complete detail the internal structure of the major dune types at White Sands Long, steep crossbeds typify the internal structure of barchanoid dunes with large slipfaces. Crossbedding and main bounding surfaces present in the main and cross trenches for barchan and transverse ridge dunes.

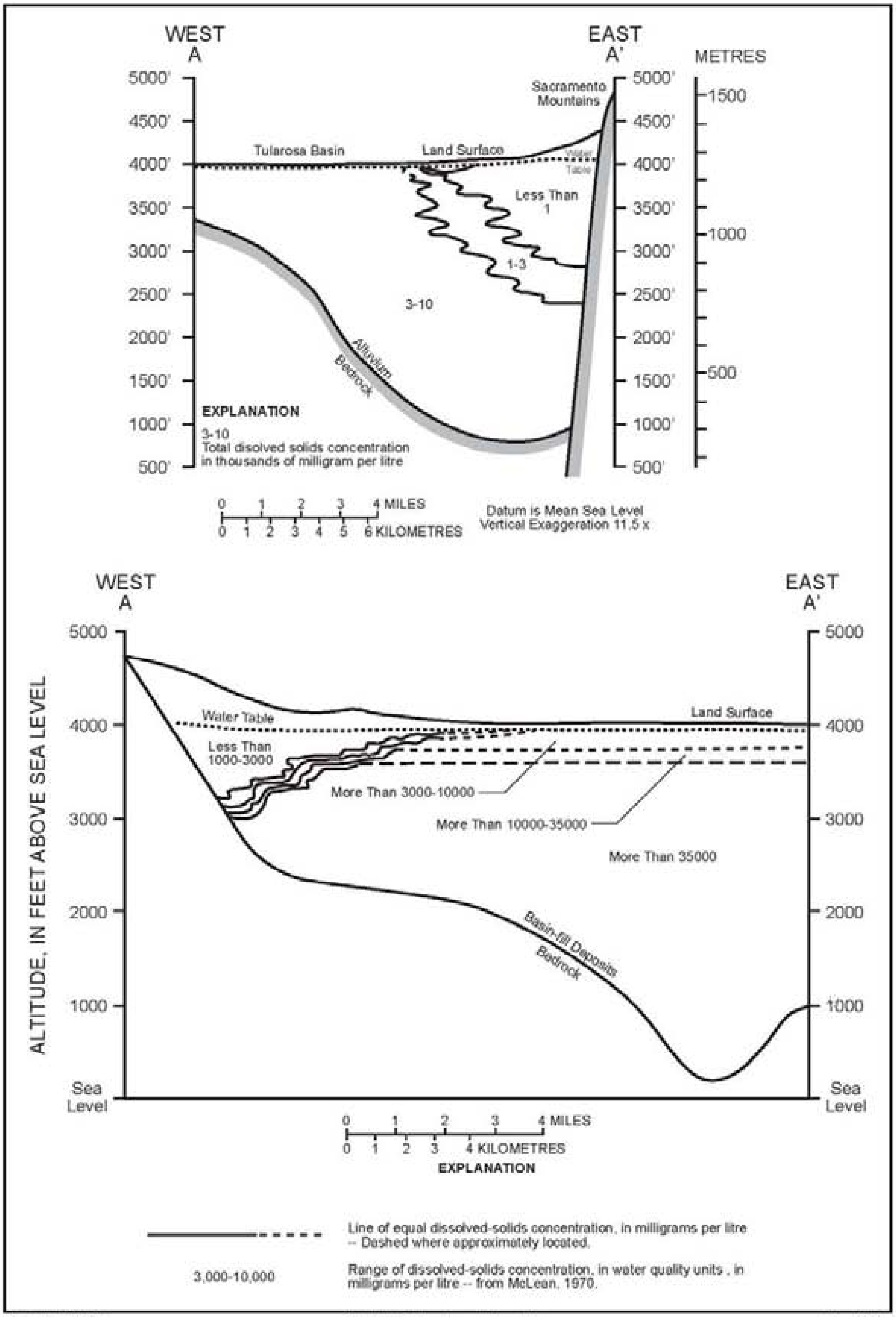
# Rate of dune advance

Rates of dune advance at White Sands were measured by McKee and Douglass (1971) who measured dune advance rates using stakes in front of the dunes from 1962 to 1968, as summarized in Table 4-1.

**Table 4-1:** Rates of movement determined by measurements of distances of aerial photographs

| **Type of dune** | **Dune number** | **Average rate of movement** *ft/year* |
|---|---|---|
| *Dome* | 2 | 24 |
| | 11 | 33 |
| | 11a | 38 |
| | 12 | 36 |
| *Transverse/Barchanoid ridge* | 3 | 5 |
| | 4 | 4 |
| | 13 | 9 |
| | 14 | 12 |
| *Barchan* | 5 | 10 |
| | 6 | 9 |
| | 15 | 7 |
| *Parabolic* | 7 | 7 |
| | 8 | 2 |
| | 16 | 0 |

Figure 3-3

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April 2000

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## Tuesday Tour

# Jornada Experimental Range and LTER

The mission of Range Management Research at the Jornada Experimental Range is to produce new knowledge of ecosystem processes for development of technologies for monitoring, assessment, remediation and management of desert rangelands. This knowledge has application to hundreds of millions of acres of public and privately owned rangeland in the United States. Remediation is both the cessation of rangeland degradation, if occurring, and the restoration of land resources through the use of economically and ecologically appropriate technologies. Extensive interagency efforts involving the National Science Foundation, the Department of Interior, other USDA agencies, non-government organizations, and many universities in both agricultural and biological sciences augment the in-house research program. International agreements on three other continents extend this mission to the one-third of the world that is rangeland.

The science program traces back to field research initiated by the U.S. Department of Agriculture in 1912 when the 78,000 ha Jornada Experimental Range was first established by Presidential Executive Order.

As a site within the National Science Foundation's Long-Term Ecological Research network, these activities are built on strong collaborations with other institutions and agencies interested in deserts, desert agriculture, desert ecology, and the management of desert rangelands. Our program is embedded within a larger research context in the Jornada Basin, the surrounding region, and in other deserts around the nation and the world where USDA, New Mexico State University, and our collaborating scientists work on objectives central to this mission or related topics.

**Tour Schedule**
Each person will stay on the same bus for the morning, early- and late-afternoon tours. Each bus will go to a different workshop during each tour period. Everyone will be able to attend all 3 workshops if they stay with the same bus all day.

| | Tuesday schedule | |
|---|---|---|
| 7:30 – 7:45 | | Orientation and board buses |
| 7:45 | | Depart for Jornada |
| 8:30 - 10:45 | Morning tour | Workshop 1 -- Desert Project/Gypsum<br>Workshop 2 -- Ecological Sites<br>Workshop 3 -- Dynamic Soil Properties |
| 10:45 | | Depart for Headquarters |
| 11: 00 - 11:45 | LUNCH | |
| 11:45 | | Depart for next tour |
| 12:00 - 2:15 | Early afternoon tour | Workshop 1 -- Desert Project/Gypsum<br>Workshop 2 -- Ecological Sites<br>Workshop 3 -- Dynamic Soil Properties |
| 2:15 | | Depart for Headquarters |
| 2:30 - 2:45 | BREAK | |
| 2:45 | | Depart for next tour |

# Workshop 1 - Desert Project and Gypsiferous Soil

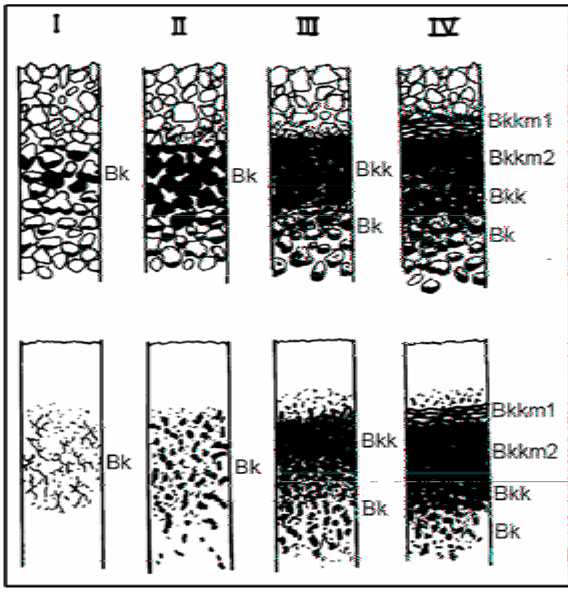
**Stop 1 San Agustin Pass Overview:** (Top) Desert Project location with respect to Basin and Range Province and Jornada Experimental Range (Bottom).

**Climatic Information:** (Top) Soil moisture regimes and (Bottom) boundary of Chihuahuan Desert in yellow based on an aridity index (Ia) ≤ 10, where Ia = Annual ppt (mm)/(annual temp (°C) + 10).


**Desert Project Overview at TWest:** Block diagram showing landforms and subsurface geology of Desert Project and Jornada Basin LTER research areas. Soil profiles to be viewed on Tuesday tour will be at TWest, ESD, and Jornada Exp Range Headquarters. After Monger et al. 2006. Regional setting of the Jornada LTER. p. 15-43. *In* K. Havstad, et al., eds. *Structure and function of a Chihuahuan Desert ecosystem: the Jornada Basin Long Term Ecological Research site.* Oxford Univ. Press, Oxford.

Schematic diagram of diagnostic carbonate morphology for the stages of carbonate accumulation in the two morphogenetic sequences (left below). Stages are described (right below), including stages V and VI not shown in diagram.

**Carbonate Morphogenetic Stages**




**Definitions of Carbonate Morphogenetic Stages**

| | Diagnostic carbonate morphology | |
|---|---|---|
| Stage | Gravelly sequence[1] | Nongravelly sequence |
| I | Thin pebble coatings, continuous in last part of stage. | Few[2] filaments, masses, or faint coatings. |
| II | Continuous pebble coatings, some interpebble masses. | Few to common nodules or masses. |
| III | Many interpebble masses; plugged horizon[3] develops in last part of stage. | Many nodules and internodular masses; plugged horizon develops in last part of stage. |
| IV | Laminar horizon overlying plugged horizon. | Laminar horizon overlying plugged horizon. |
| V | Very strongly cemented to indurated with > 1 cm thick laminae; may contain pisoliths and have vertical faces and fractures coated with laminated carbonate. | |
| VI | Indurated with multiple generations of recemented laminae, breccia, and pisoliths. | |

1 Morphologies are best expressed where "nongravelly" materials contain less than about 20 % by volume of rock fragments (fragments 2 mm or larger in diameter), and "gravelly" materials contain more than about 60 % by volume of rock fragments. Materials that have between 20 % and 60 % by volume of rock fragments have intermediate morphologies.

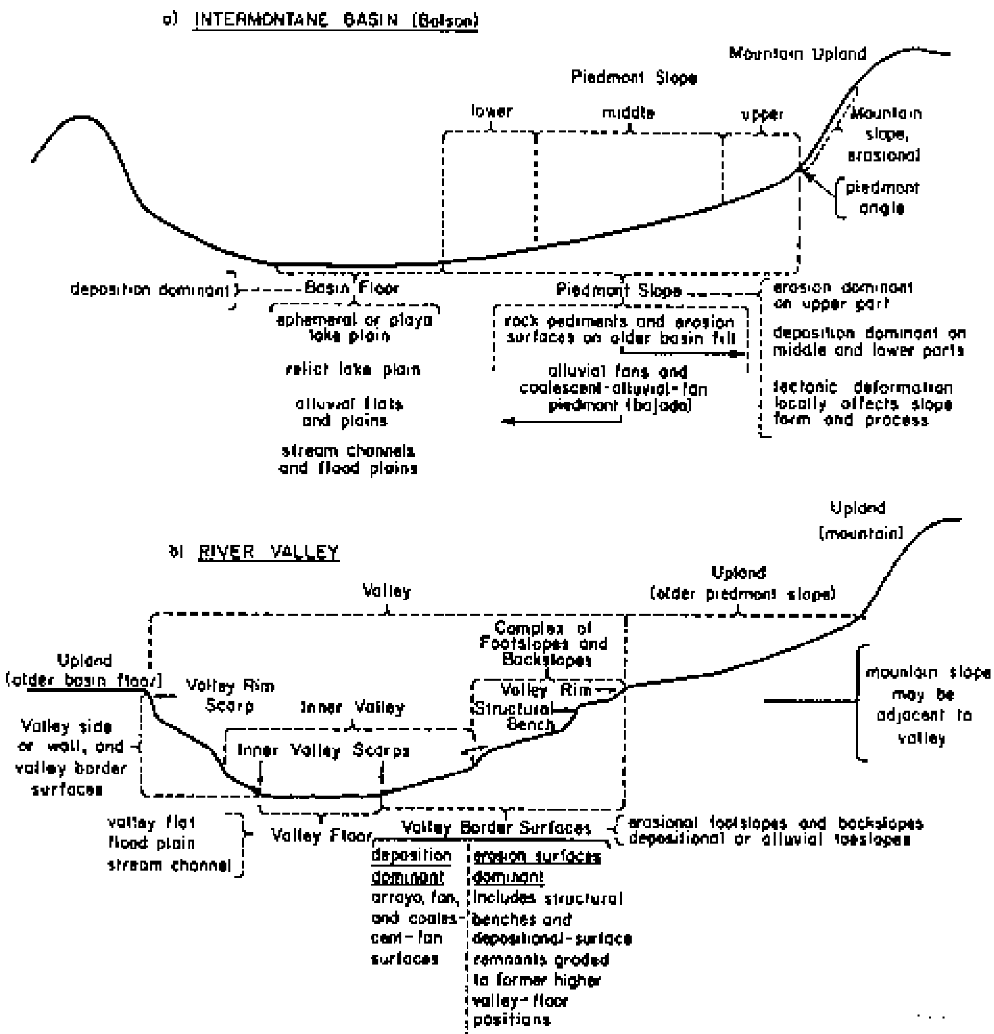
2 Few < 2, common 2 to < 20, many = 20 or greater percent of area covered.

3 Plugged horizon contains 50 percent or more pedogenic carbonate (by vol).

**Desert Project Overview at TWest:** Morphogenetic stages of pedogenic carbonate accumulation. Modified from Gile, L.H., Peterson, F.F., and Grossman, R.B., 1966, Morphological and genetic sequences of carbonate accumulation in desert soils: Soil Science, v. 101, no. 5, p. 347-360

**Table of Geomorphic Surfaces:** The age of a geomorphic surface and its soils is considered to be the same. On a constructional surface, for example, all would date from the approximate time that sedimentation stopped and soil development started.

| Geomorphic surface | | | Carbonate stage | | Estimated soil age |
|---|---|---|---|---|---|
| **Valley border** | **Piedmont slope** | **Basin floor** | **Nongravelly materials** | **Gravelly materials** | **(years B.P. or epoch)** |
| Coppice dunes | Coppice dunes | Whitebottom | | | Historical (since 1850 A.D.) |
| | | Lake Tank | | | present to 150,000 |
| | | | | | Middle to late Holocene |
| Fillmore | Organ | | 0, I | I | 100 – 7,000 |
| | III | | I | I | 100(?) – 1,000 |
| | II | | I | I | 1,100 – 2,100 |
| | I | | I | I | 2,200 – 7,000 |
| Leasburg | Isaacks' Ranch | | II | II, III | Latest Pleistocene (10,000 – 15,000) |
| Butterfield | Baylor | | III | III | Late Pleistocene (15,000 – 100,000) |
| Picacho | Jornada II | Petts Tank | III | III, IV | Late to middle Pleistocene (100,000 -250,000) |
| Tortugas | Modoc | | III | IV | Late middle Pleistocene (250,000 – 500,000) |
| Jornada I | Jornada I | Jornada I | III | IV | Middle Pleistocene (500,000 – 700,000) |
| | Doña Ana | | | IV | >700,000 |
| Buried surfaces and soils | | | | | 700,000 – 2,000,000 |
| Lower La Mesa | | | III, IV | | Middle to early Pleistocene (780,000) |
| JER La Mesa | | | IV, V | | Early Pleistocene to Late Pliocene (780,000-2,000,000) |
| Upper La Mesa | | | V | | Late Pliocene (2,000,000 – 2,500,000) |




**Desert Project Overview:** Landform profiles in the Desert Project. Top profile is of intermontane landforms. Bottom profile is of river valley landforms. From Gile, L.H., Hawley, J.W., and Grossman, R.B. 1981, Soils and geomorphology in the Basin and Range area of Southern New Mexico—Guidebook to the Desert Project: New Mexico Bureau of Mines and Mineral Resources, Memoir 39, 222 p.

**TWest Micromorphology** of calcic horizon showing progressive magnifications of areas located with arrows. Top shows biogenic carbonate in the form of a calcified filament.

# TWest Profile Description

USDA NRCS Pedon Description

## PEDON DESCRIPTION

**Print Date:** 07/20/2005
**Description Date:** 06/07/2004
**Describer:** C. Monger, R. Burt, D. Sprankle, G. Cates, W. Shoup, R. Kraimer, V. Anne
**Site ID:** S04NM013-001

**Site Note:**
**Pedon ID:** 04NM013001
**Pedon Note:**

**Lab Source ID:** SSL
**Lab Pedon #:** 04N0942
**Soil Name as Described/Sampled:** T-WEST
**Soil Name as Correlated:**
**Classification:** Fine-loamy, mixed, superactive, thermic Ustic Haplargids
**Pedon Type:**
**Pedon Purpose:** research site

**Taxon Kind:**

**Associated Soils:**
**Physiographic Division:** Intermontane Plateaus
**Physiographic Province:** Basin and Range Province
**Physiographic Section:** Mexican Highland

**State Physiographic Area:**
**Local Physiographic Area:**
**Geomorphic Setting:** alluvial flat
basin floor
**Upslope Shape:**
**Cross Slope Shape:**
**Particle Size Control Section:** 30 to 80 cm.
**Diagnostic Features:** ochric epipedon 0 to 18 cm.
argillic horizon 30 to 150 cm.
calcic horizon 62 to 183 cm.

**Country:**
**State:** New Mexico
**County:** Dona Ana
**MLRA:** 42 -- Southern Desertic Basins, Plains, and Mountains

**Soil Survey Area:**
**Map Unit:**
**Quad Name:** Taylor Well, New Mexico

**Location Description:**
**Legal Description:**
**Latitude:**
**Longitude:**
**Datum:** NAD83
**UTM Zone:** 13
**UTM Easting:** 336268 meters
**UTM Northing:** 3598627 meters

**Primary Earth Cover:**
**Secondary Earth Cover:**
**Existing Vegetation:** honey mesquite, Yucca, black grama
**Parent Material:** Igneous
**Bedrock Kind:**
**Bedrock Depth:**
**Bedrock Hardness:**
**Bedrock Fracture Interval:**
**Surface Fragments:**

A1--0 to 10 centimeters; brown (7.5YR 5/4) crushed fine sandy loam, dark yellowish brown (10YR 3/6) crushed, moist; 13 percent clay; weak fine platy, and weak medium platy structure; very friable, slightly hard, nonsticky, nonplastic; common fine roots throughout and common very fine roots throughout; common fine dendritic tubular and common medium dendritic tubular pores; strong effervescence, by HCl, 1 normal; abrupt smooth boundary. Lab sample # 04N05151

A2--10 to 18 centimeters; light brown (7.5YR 6/4) crushed sandy clay loam, brown (7.5YR 4/4) crushed, moist; 24 percent clay; moderate medium subangular blocky structure; very friable, moderately hard, slightly sticky, moderately plastic; common very fine roots throughout; common fine dendritic tubular and common medium tubular pores; strong effervescence, by HCl, 1 normal; clear smooth boundary. Lab sample # 04N05152

BA--18 to 30 centimeters; light brown (7.5YR 6/4) crushed sandy clay loam, strong brown (7.5YR 4/6) crushed, moist; 24 percent clay; moderate medium subangular blocky structure; friable, moderately hard, slightly sticky, slightly plastic; many fine roots throughout and many very fine roots throughout; common fine dendritic tubular and common very fine tubular and common very fine vesicular pores; 1 percent fine threadlike carbonate masses on faces of peds; 1 percent subrounded 2- to 5-millimeter igneous rock fragments; strong effervescence, by HCl, 1 normal; clear smooth boundary. Lab sample # 04N05153

Btk1--30 to 50 centimeters; brown (7.5YR 5/4) crushed sandy clay loam, brown (7.5YR 4/4) crushed, moist; 26 percent clay; moderate medium subangular blocky, and moderate fine subangular blocky structure; friable, hard, moderately sticky, moderately plastic; common fine roots throughout and common very fine roots throughout; common fine vesicular and common very fine dendritic tubular and common very fine tubular pores; 15 percent distinct clay films on all faces of peds; 1 percent fine dendritic carbonate masses on faces of peds and 1 percent fine threadlike carbonate masses on faces of peds; 3 percent subrounded 2- to 20-millimeter igneous rock fragments; strong effervescence, by HCl, 1 normal; clear smooth boundary. Lab sample # 04N05154

Btk2--50 to 62 centimeters; reddish yellow (7.5YR 6/6) crushed sandy clay loam, strong brown (7.5YR 4/6) crushed, moist; 32 percent clay; weak medium subangular blocky structure; friable, hard, very sticky, very plastic; common very fine roots throughout; common very fine vesicular and common very fine tubular pores; 8 percent faint clay films on all faces of peds; 4 percent fine threadlike carbonate masses on faces of peds and 1 percent medium cylindrical carbonate masses infused into matrix along faces of peds; 2 percent subrounded 2- to 20-millimeter igneous rock fragments; strong effervescence, by HCl, 1 normal; clear smooth boundary. Lab sample # 04N05155

Btk3--62 to 87 centimeters; pink (7.5YR 7/3) crushed clay loam, strong brown (7.5YR 4/6) crushed, moist; 30 percent clay; weak medium subangular blocky, and weak fine subangular blocky structure; firm, hard, moderately sticky, moderately plastic; common very fine roots throughout; common very fine tubular pores; 5 percent faint clay films on all faces of peds; 25 percent medium irregular carbonate masses on faces of peds; 7 percent subrounded 2- to 20-millimeter igneous rock fragments; violent effervescence, by HCl, 1 normal; gradual smooth boundary. Lab sample # 04N05156

Btk4--87 to 110 centimeters; pink (7.5YR 7/3) crushed sandy clay loam, brown (7.5YR 5/4) crushed, moist; 30 percent clay; weak medium subangular blocky structure; very friable, very hard, moderately sticky, moderately plastic; common very fine roots throughout; common fine dendritic tubular and common medium dendritic tubular and common very fine tubular pores; 2 percent faint clay films on all faces of peds; 15 percent medium irregular carbonate masses on faces of peds; 10 percent subrounded 2- to 20-millimeter igneous rock fragments; violent effervescence, by HCl, 1 normal; gradual smooth boundary. Lab sample # 04N05157

Btk5--110 to 150 centimeters; pink (7.5YR 7/3) crushed gravelly sandy clay loam, pink (7.5YR 7/4) crushed, moist; 24 percent clay; moderate fine subangular blocky structure; friable, extremely hard, moderately sticky, moderately plastic; few very fine roots throughout; common fine tubular and common very fine vesicular pores; 2 percent faint clay films on all faces of peds; 35 percent medium irregular carbonate masses on faces of peds; 34 percent subrounded 2- to 20-millimeter igneous rock fragments; violent effervescence, by HCl, 1 normal; gradual smooth boundary. Lab sample # 04N05158

Bk--150 to 183 centimeters; pink (7.5YR 8/3) crushed gravelly sandy clay loam, pink (7.5YR 7/4) crushed, moist; 23 percent clay; moderate medium subangular blocky structure; friable, very hard, slightly sticky, slightly plastic; very few very fine roots throughout; common medium tubular pores; 85 percent coarse irregular carbonate masses in matrix; 60 percent subrounded 2- to 20-millimeter igneous rock fragments; violent effervescence, by HCl, 1 normal. Lab sample # 04N05159

PSDA & Rock Fragments

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17-

| | | | | (- - - - - Total - - - - - -) | | | (- - Clay - - -) | | (- - - - Silt - - - - -) | | (- - - - - - - - - - - - - Sand - - - - - - - - - - - - -) | | | | | ( Rock Fragments (mm) ) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Clay | Silt | Sand | Fine | $CO_3$ | Fine | Coarse | VF | F | M | C | VC | (- - - - - - - - Weight - - - - - - - -) | | | | >2 mm |
| | | | | < | .002 | .05 | < | < | .002 | .02 | .05 | .10 | .25 | .5 | 1 | 2 | 5 | 20 | .1- | wt % |
| | Depth | | | .002 | -.05 | -2 | .0002 | .002 | -.02 | -.05 | -.10 | -.25 | -.50 | -1 | -2 | -5 | -20 | -75 | 75 | whole |
| Layer | (cm) | Horz | Prep | (- - - - - - - - - - - - - - - - - - - - - - - - - % of <2mm Mineral Soil - - - - - - - - - - - - - - - - - - - - - - - - - - -) | | | | | | | | | | | | (- - - - - - - % of <75mm - - - - - -) | | | | soil |
| | | | | 3A1a1a | | | 3A1a1a | 3A1a1a | 3A1a1a | | 3A1a1a | 3A1a1a | 3A1a1a | 3A1a1a | 3A1a1a | | | | | |
| 04N05151 | 0-10 | A1 | S | 17.9 | 31.1 | 51.0 | 5.4 | -- | 12.7 | 18.4 | 16.9 | 17.2 | 12.9 | 3.9 | 0.1 | | | | 34 | |
| 04N05152 | 10-18 | A2 | S | 22.0 | 25.3 | 52.7 | 5.4 | 1.3 | 11.5 | 13.8 | 14.5 | 17.9 | 14.6 | 5.6 | 0.1 | | | | 38 | |
| 04N05153 | 18-30 | BA | S | 26.9 | 25.6 | 47.5 | 9.2 | 4.4 | 12.3 | 13.3 | 11.7 | 16.8 | 12.6 | 5.7 | 0.7 | | | | 36 | |
| 04N05154 | 30-50 | Btk1 | S | 29.2 | 26.6 | 44.2 | 12.2 | 2.1 | 13.3 | 13.3 | 12.3 | 13.1 | 11.8 | 5.8 | 1.2 | | | | 32 | |
| 04N05155 | 50-62 | Btk2 | S | 39.3 | 24.2 | 36.5 | 15.3 | 13.3 | 13.8 | 10.4 | 9.5 | 11.7 | 9.2 | 5.5 | 0.6 | | | | 27 | |
| 04N05156 | 62-87 | Btk3 | S | 37.8 | 24.2 | 38.0 | 11.8 | 19.8 | 15.4 | 8.8 | 9.6 | 11.7 | 9.6 | 6.7 | 0.4 | | | | 28 | |
| 04N05157 | 87-112 | Btk4 | S | 32.1 | 27.5 | 40.4 | 8.9 | 21.0 | 19.6 | 7.9 | 8.2 | 12.5 | 8.9 | 6.8 | 4.0 | | | | 32 | |
| 04N05158 | 112-150 | Btk5 | S | 32.6 | 31.9 | 35.5 | 6.6 | 25.7 | 25.1 | 6.8 | 8.6 | 11.2 | 9.0 | 5.0 | 1.7 | | | | 27 | |
| 04N05159 | 150-180 | Bk | S | 33.0 | 30.1 | 36.9 | 8.3 | 22.3 | 23.5 | 6.6 | 9.8 | 12.7 | 8.5 | 4.7 | 1.2 | | | | | |

Bulk Density & Moisture

| | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- | -12- | -13- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Bulk Density) | | Cole | (- - - - - - - - - - - Water Content - - - - - - - - - - -) | | | | | | WRD | Aggst | | |
| | | | | 33 | Oven | Whole | 6 | 10 | 33 | 1500 | 1500 kPa | Ratio | Whole | Stabl | (- - Ratio/Clay - -) | |
| | Depth | | | kPa | Dry | Soil | kPa | kPa | kPa | kPa | Moist | AD/OD | Soil | 2-0.5mm | CEC7 | 1500 kPa |
| Layer | (cm) | Horz | Prep | (- - - g $cm^{-3}$ - - -) | | | (- - - - - - - - - - - - pct of < 2mm - - - - - - - - - - - -) | | | | | | $cm^3$ $cm^{-3}$ | % | | |
| | | | | 3B1b | 3B1c | | 3C1a | 3C1b | 3C1c | 3C2a1a | | 3D1 | | | | |
| 04N05151 | 0-10 | A1 | S | 1.48 | 1.55 | 0.016 | 20.2 | 19.0 | 16.4 | 8.1 | | 1.028 | 0.12 | | 0.91 | 0.45 |
| 04N05152 | 10-18 | A2 | S | 1.41 | 1.50 | 0.021 | 21.8 | 20.2 | 17.3 | 9.3 | | 1.032 | 0.11 | | 0.73 | 0.42 |
| 04N05153 | 18-30 | BA | S | 1.35 | 1.44 | 0.022 | 23.3 | 21.8 | 18.7 | 10.3 | | 1.033 | 0.11 | | 0.54 | 0.38 |
| 04N05154 | 30-50 | Btk1 | S | 1.46 | 1.56 | 0.022 | 22.2 | 21.3 | 18.8 | 10.7 | | 1.035 | 0.12 | | 0.51 | 0.37 |
| 04N05155 | 50-62 | Btk2 | S | 1.44 | 1.59 | 0.034 | 25.4 | 24.2 | 20.7 | 12.6 | | 1.038 | 0.12 | | 0.39 | 0.32 |
| 04N05156 | 62-87 | Btk3 | S | 1.40 | 1.53 | 0.030 | 25.1 | 23.8 | 20.6 | 10.2 | | 1.029 | 0.15 | | 0.30 | 0.27 |
| 04N05157 | 87-112 | Btk4 | S | 1.53 | 1.63 | 0.021 | 20.3 | 19.1 | 16.4 | 7.9 | | 1.021 | 0.13 | | 0.24 | 0.25 |
| 04N05158 | 112-150 | Btk5 | S | 1.52 | 1.58 | 0.013 | 21.0 | 19.9 | 17.1 | 7.1 | | 1.017 | 0.15 | | 0.17 | 0.22 |
| 04N05159 | 150-180 | Bk | S | 1.55 | 1.69 | 0.029 | 20.6 | 19.5 | 17.5 | 8.4 | | 1.020 | 0.14 | | 0.16 | |

Carbon & Extractions

| | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- | -12- | -13- | -14- | -15- | -16- | -17- | -18- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (- - - - - Total - - - - -) | | | Org | C/N | (- - - Dith-Cit Ext - - -) | | | (- - - - - - - - Acid Oxalate Extraction - - - - - - - -) | | | | | | (- - - Na Pyro-Phosphate - - -) | | | |
| | Depth | | | C | N | S | C | Ratio | Fe | Al | Mn | Al+½Fe | ODOE | Fe | Al | Mn | Si | C | Fe | Al | Mn |
| Layer | (cm) | Horz | Prep | (- - - - - - % of <2 mm - - - - - -) | | | | | (- - - - - - - - - - - - - - - - % of < 2mm - - - - - - - - - - - - - - -) | | | | | | | mg kg$^{-1}$ | (- - - - - - - - - % of < 2mm - - - - - - - - - -) | | | | |
| | | | | 4H2a | 4H2a | 4H2a | | | 4G1 | 4G1 | 4G1 | | 4G2a | 4G2a | 4G2a | 4G2a | 4G2a | | 4G3 | 4G3 | 4G3 |
| 04N05151 | 0-10 | A1 | S | 1.06 | 0.092 | 0.01 | | 9 | 0.8 | 0.1 | tr | 0.16 | 0.02 | 0.07 | 0.13 | 217.6 | 0.07 | | -- | -- | -- |
| 04N05152 | 10-18 | A2 | S | 1.08 | 0.061 | 0.01 | | 10 | 0.7 | 0.1 | tr | 0.15 | 0.03 | 0.07 | 0.12 | 218.9 | 0.07 | | -- | -- | -- |
| 04N05153 | 18-30 | BA | S | 1.53 | 0.045 | 0.01 | | 10 | 0.7 | 0.1 | tr | 0.14 | 0.03 | 0.07 | 0.11 | 165.5 | 0.07 | | -- | -- | -- |
| 04N05154 | 30-50 | Btk1 | S | 1.60 | 0.050 | 0.01 | | 9 | 0.7 | 0.1 | tr | 0.14 | 0.02 | 0.07 | 0.10 | 169.6 | 0.07 | | -- | -- | -- |
| 04N05155 | 50-62 | Btk2 | S | 2.71 | 0.039 | 0.01 | | 13 | 0.5 | tr | tr | 0.12 | 0.02 | 0.07 | 0.09 | 104.0 | 0.06 | | -- | -- | -- |
| 04N05156 | 62-87 | Btk3 | S | 4.08 | 0.019 | 0.01 | | 21 | 0.3 | tr | -- | 0.09 | 0.01 | 0.04 | 0.06 | 60.7 | 0.05 | | -- | -- | -- |
| 04N05157 | 87-112 | Btk4 | S | 5.09 | 0.016 | 0.01 | | 11 | 0.2 | tr | -- | 0.06 | 0.01 | 0.03 | 0.04 | 30.5 | 0.03 | | -- | -- | -- |
| 04N05158 | 112-150 | Btk5 | S | 6.56 | 0.007 | 0.01 | | 20 | 0.1 | -- | -- | 0.05 | tr | 0.03 | 0.03 | 20.2 | 0.02 | | -- | -- | -- |
| 04N05159 | 150-180 | Bk | S | 5.76 | 0.003 | 0.02 | | 71 | 0.1 | -- | -- | 0.05 | 0.01 | 0.03 | 0.03 | 19.4 | 0.04 | | -- | -- | -- |

Pedon ID: S04NM-013-001 ( Dona Ana County, New Mexico ) Print Date: Jul 29 2005 3:28PM

Sampled As : Fine-loamy, mixed, superactive, thermic Ustic Haplargid

USDA-NRCS-NSSC-National Soil Survey Laboratory ; Pedon No.

pH & Carbonates

| | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (- - - - - - - - - - - - - - - - - pH - - - - - - - - - - - - - - - - -) | | | | | | (- - Carbonate - -) | | (- - Gypsum - - -) | | |
| | | | | | $CaCl_2$ | | | | | As $CaCO_3$ | | As $CaSO_4$*$2H_2O$ | | Resist |
| | Depth | | | | 0.01M | $H_2O$ | Sat | | | <2mm | <20mm | <2mm | <20mm | ohms |
| Layer | (cm) | Horz | Prep | KCl | 1:2 | 1:1 | Paste | Sulf | NaF | (- - - - - - - - - - - - % - - - - - - - - - - - -) | | | | cm$^{-1}$ |
| | | | | | 4C1a2a2 | 4C1a2a1 | 4C1a1a2 | | | 4E1a1a1a1 | | | | |
| 04N05151 | 0-10 | A1 | S | | 7.9 | 8.4 | | | | 2 | | | | |
| 04N05152 | 10-18 | A2 | S | | 8.0 | 8.5 | | | | 4 | | | | |
| 04N05153 | 18-30 | BA | S | | 7.9 | 8.5 | | | | 9 | | | | |
| 04N05154 | 30-50 | Btk1 | S | | 7.9 | 8.4 | | | | 9 | | | | |
| 04N05155 | 50-62 | Btk2 | S | | 8.0 | 8.4 | | | | 18 | | | | |
| 04N05156 | 62-87 | Btk3 | S | | 8.0 | 8.5 | | | | 31 | | | | |
| 04N05157 | 87-112 | Btk4 | S | | 8.0 | 8.5 | | | | 41 | | | | |
| 04N05158 | 112-150 | Btk5 | S | | 8.2 | 8.6 | | | | 54 | | | | |
| 04N05159 | 150-180 | Bk | S | | 8.4 | 8.6 | 8.3 | | | 46 | | | | |

**Stellar (Ustic Calciargid) Water content, including run-in water.**

Illustration of the importance of run-in water in TWest vicinity. After Herbel, C.H., Gile, L.H., Fredrickson, E.L., and Gibbens, R.P., 1994. Soil water and soils at soil water sites, Jornada Experimental Range. L.H. Gile and R.J. Ahrens (eds.) Soil Survey Investigations Report No. 44. Soil Conservation Service, Lincoln, NE.

**Gypsum Profile at JER Headquarters:** From Herbel, C.H., Gile, L.H., Fredrickson, E.L., and Gibbens, R.P., 1994, Soil water and soils at soil water sites, Jornada Experimental Range. L.H. Gile and R.J. Ahrens (eds.) Soil Survey Investigations Report No. 44. Soil Conservation Service, Lincoln, NE.

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USDA-Soil Conservation Service
Pedon Narrative Description
Soil Series: Wink, deep gypsum phase
Classification: Coarse-loamy, mixed, thermic Typic Calciorthid
NSSL ID#: 90P0495
Soil Survey #: S90NM-013-004
Location: The SE1/4NE1/NW1/4 section 33, T.19S., R.2E., in the former exclosure at Headquarters. This exclosure has been dismantled and the rain gauge has been moved to another site at Headquarters. ARS personnel indicate that the sampled pedon is very close to the former location of the soil moisture blocks.

Elevation: 4320 ft, 1317 m
Landform: Ridge side sloping 2% to the east
Geomorphic Surface: Eolian analogue of Jornada II, late phase?
Parent Material: Late phase Jornada II (?) sand
Vegetation: Dropseed, soaptree yucca, fourwing saltbush
Described By: L.H. Gile
Date: Jan. 29, 1990

Soil surface: A layer of loose reddish sand occurs over most of the surface.

C--0 to 9 cm; stratified pinkish gray to light brown (7.5YR 6/3) loamy sand; brown (7.5YR 4.5/3) moist; massive but with horizontal cleavage to thin and medium lenses; generally soft, with some lenses separated by soft fine granules or loose, single-grain material; few and common fine roots; 90P2736; strongly effervescent; abrupt smooth boundary.

Ab--9 to 18 cm; brown (7.5YR 5/2.5) loamy sand; dark brown (7YR 3.5/3) moist; very weak medium subangular blocky structure; slightly hard, very friable; few fine roots; 90P2737; strongly effervescent; clear wavy boundary.

Akb--18 to 30 cm; pinkish gray to light brown (7.5YR 6/3) loamy sand; brown to dark brown (7.5YR 4/3) moist; very weak medium subangular blocky structure; slightly hard, very friable; few fine roots; 90P2738; very few carbonate filaments; strongly effervescent; clear wavy boundary.

Bk1b--30 to 42 cm; pinkish gray to light brown (7.5YR 6.5/3) fine sandy loam; brown (7.5YR 5/3.5) moist; weak medium subangular blocky structure; slightly hard and hard, very friable; few fine roots; 90P2739; very few filaments; strongly effervescent; clear wavy boundary.

Bk2b--42 to 58 cm; pinkish gray to light brown (7.5YR 6.5/3) fine sandy loam; brown (7.5YR 5/3.5) moist; weak medium subangular blocky structure; slightly hard and hard, friable, few fine roots; 90P2740; few carbonate filaments; strongly effervescent; clear wavy boundary.

Bk3b--58 to 78 cm; pinkish gray to pink (7.5YR 7/3) fine sandy loam; brown (7.5YR 5/3.5) moist; weak medium subangular blocky structure; slightly hard and hard, friable; few fine roots; 90P2741; few carbonate filaments; strongly effervescent; clear wavy boundary.

K2b--78 to 101 cm; pinkish gray to pink (7.5YR 7.5/3) sandy clay loam; pinkish gray to light brown (7.5YR 6/3) moist; occurring as nodules and as internodular K-fabric, with lesser amount of 7.5YR 9/2 and 8/2; moderate medium subangular blocky structure; hard and very hard, firm; very few fine mottles; strongly effervescent; clear wavy boundary.

K3b--101 to 117 cm; pinkish gray to pink (7.5YR 7.5/3) sandy clay loam; pinkish gray to light brown (7.5YR 6/3) moist; these colors occur as carbonate nodules and as internodular K-fabric with lesser amount of 7.5YR 9/2, 8/2, and 6.5/3; moderate medium subangular blocky structure; very hard, firm; very few fine roots; 90P2743; few medium yellow and brownish yellow (10YR 7/6. 6/6) mottles; strongly effervescent; clear wavy boundary.

Bkb--117 to 127 cm; pinkish gray to light brown (7.5YR 6.5/3) sandy clay loam; brown (7.5YR 5/3) moist; weak medium subangular blocky structure; fine yellow and brownish yellow (10YR 7/6, 6/6) mottles and streaks; strongly effervescent; abrupt smooth boundary.

C--127 to 136 cm; white (10YR 9/2) sandy loam; very pale brown (10YR 8/3) moist; weak medium and coarse subangular blocky structure; very hard, firm; no roots; 90P2745; some parts noncalcareous, other parts weakly or strongly effervescent. This material appears to be primarily gypsum, and needs further study. It may be partly or wholly of lacustrine origin.

S90NM-013-004 *** PRIMARY CHARACTERIZATION DATA ***

PRINT DATE 91/29/9?

Soil series: Wink, deep gypsum phase, COARSE-LOAMY, MIXED, THERMIC TYPIC CALCIORTHID

NSSL - PROJECT 90P 78, DONA ANA CO.
- PEDON 90P 495, SAMPLES 90P2736-2745
- GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA 68508-3866

| SAMPLE NO. | DEPTH (CM) | HORIZON | -1- CLAY LT .002 | -2- SILT .002-.05 | -3- SAND .05-2 | -4- FINE CLAY LT .0002 | -5- CO3 CLAY LT .002 | -6- FINE SILT .002-.02 | -7- COARSE SILT .02-.05 | -8- VF SAND .05-.10 | -9- F SAND .10-.25 | -10- M SAND .25-.50 | -11- C SAND .5-1 | -12- VC SAND 1-2 | -13- WEIGHT 2-5 | -14- WEIGHT 5-20 | -15- WEIGHT 20-75 | -16- .1-75 PCT OF <75MM (3B1) | -17- >2MM WT PCT OF WHOLE SOIL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90P2736S | 0- 9 | C | 6.4 | 4.5 | 89.1 | | | 2.5 | 2.0 | 10.0 | 41.0 | 24.7 | 2.5 | 0.1 | -- | -- | -- | 69 | -- |
| 90P2737S | 9- 18 | AB | 9.3 | 6.6 | 84.1 | | 0.9 | 3.5 | 3.1 | 16.0 | 42.6 | 25.1 | 2.1 | 0.1 | -- | -- | -- | 66 | -- |
| 90P2738S | 18- 30 | ABk | 10.6 | 3.9 | 85.5 | | 0.9 | 3.0 | 0.9 | 16.6 | 40.9 | 25.3 | 2.6 | 0.1 | -- | -- | -- | 69 | -- |
| 90P2739S | 30- 42 | Bk1 | 12.7 | 5.9 | 81.4 | | 2.4 | 3.4 | 2.1 | 14.0 | 39.5 | 24.4 | 3.3 | 0.2 | TR | TR | -- | 67 | -- |
| 90P2740S | 42- 58 | Bk2 | 13.4 | 7.2 | 79.4 | | 2.7 | 4.5 | 2.7 | 13.0 | 36.0 | 25.7 | 3.7 | 0.2 | TR | TR | -- | 66 | -- |
| 90P2741S | 58- 78 | Bk3 | 14.3 | 8.4 | 77.3 | | 3.4 | 5.6 | 2.8 | 13.9 | 33.4 | 25.5 | 3.6 | 0.3 | TR | TR | -- | 63 | TR |
| 90P2742S | 78-101 | K2B | 22.1 | 14.2 | 63.7 | | 7.0 | 10.7 | 3.5 | 14.4 | 25.9 | 19.2 | 3.4 | 0.6 | 1 | TR | -- | 54 | 1 |
| 90P2743S | 101-117 | K3B | 23.3 | 17.1 | 59.6 | | 2.0 | 13.3 | 4.0 | 13.3 | 25.4 | 17.0 | 3.2 | 0.7 | -- | -- | -- | 46 | -- |
| 90P2744S | 117-127 | BKB | 21.4 | 14.1 | 64.5 | | 2.5 | 8.8 | 5.3 | 14.2 | 28.1 | 18.0 | 3.5 | 0.7 | 1 | -- | -- | 51 | 1 |
| 90P2745S | 127-136 | C | 8.4 | 30.6 | 61.0 | | 1.2 | 19.5 | 11.1 | 21.5 | 24.9 | 12.9 | 1.6 | 0.1 | -- | -- | -- | 39 | -- |
| | | | | | | | | | | | | | | | -- | -- | -- | | -- |
| | | | | | | | | | | | | | | | -- | -- | -- | | -- |

Units for columns 1–12: PCT OF <2MM (3A1).

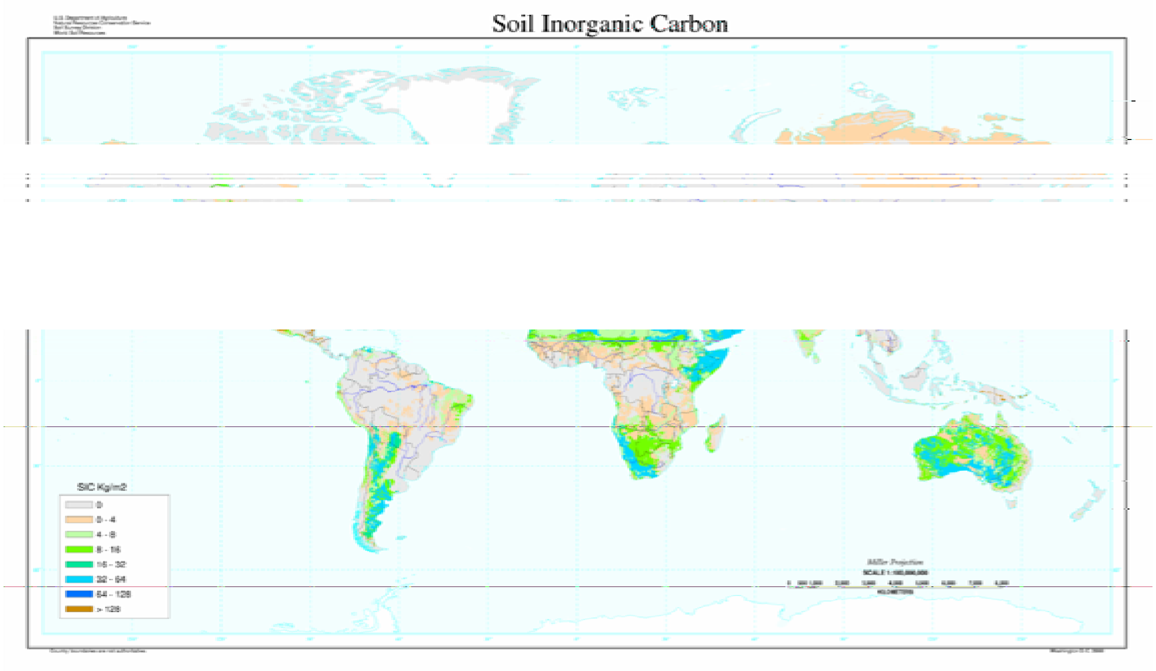
| DEPTH (CM) | ORGN C 6A1c PCT | TOTAL N 6B3a <2MM | EXTR P 6S3 PPM | TOTAL S 6R3a | DITH-CIT EXTRACTABLE FE 6C2b | AL 6G7a | MN 6D2a | RATIO/CLAY CEC 8D1 | RATIO/CLAY 15 BAR 8D1 | ATTERBERG LL 4F1 | PI 4F | BULK DENSITY FIELD MOIST 4A3a | 1/3 BAR 4A1d | OVEN DRY 4A1h | COLE WHOLE SOIL 4D1 CM/CM | WATER CONTENT FIELD MOIST 4B4 | 1/10 BAR 4B1c | 1/3 BAR 4B1c | 15 BAR 4B2a | WRD WHOLE SOIL 4C1 CM/CM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0- 9 | 0.26 | | | | | | | 0.76 | 0.35 | | | | | | | | | | 2.9 | |
| 9- 18 | 0.26 | | | | | | | 0.81 | 0.34 | | | | 1.69 | 1.73 | 0.008 | | | 4.5 | 3.2 | 0.02 |
| 18- 30 | 0.23 | | | | | | | 0.67 | 0.33 | | | | | | | | | | 3.5 | |
| 30- 42 | 0.23 | | | | | | | 0.60 | 0.35 | | | | 1.59 | 1.62 | 0.006 | | | 5.0 | 4.4 | 0.01 |
| 42- 58 | 0.21 | | | | | | | 0.35 | 0.34 | | | | | | | | | | 4.5 | |
| 58- 78 | 0.18 | | | | | | | 0.53 | 0.34 | | | | | | | | | | 4.8 | |
| 78-101 | 0.22 | | | | | | | 0.43 | 0.30 | | | | 1.57 | 1.61 | 0.019 | | | 11.2 | 6.7 | 0.07 |
| 101-117 | 0.18 | | | | | | | 0.55 | 0.33 | | | | 1.53 | 1.65 | 0.025 | | | 13.2 | 7.7 | 0.08 |
| 117-127 | 0.19 | | | | | | | 0.61 | 0.36 | | | | | | | | | | 7.7 | |
| 127-136 | 0.08 | | | | | | | 0.46 | 0.71 | | | | 1.30 | 1.30 | -- | | | 10.7 | 6.0 | 0.10 |

Units: extractable Fe, Al, Mn as PERCENT OF <2MM; Atterberg limits PCT <0.4MM; bulk density G/CC; water content PCT OF <2MM.

AVERAGES, DEPTH 25-100: PCT CLAY 12 PCT .1-75MM 61

| DEPTH (CM) | NH4OAC EXTRACTABLE BASES CA 5B5a 6N2e | MG 5B5a 6O2d | NA 5B5a 6P2b | K 5B5a 6Q2b | SUM BASES | ACIDITY 6H5a | CEC SUM CATS 5A3a | CEC NH4-OAC 5A8b | EXCH NA 5B5b PCT | SAR 5E | BASE SATURATION SUM 5C3 | BASE SATURATION NH4OAC 5C1 | CO3 AS CACO3 <2MM 6E1g PCT | RES. OHMS /CM 8E1 | CASO4 AS GYPSUM <2MM 6F1a | <20MM 6F4 | EC SAT PASTE 8C1b | PH CACL2 .01M 8C1f 1:2 | PH H2O 8C1f 1:1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0- 9 | | 0.8 | -- | 0.6 | | | | 6.4 | TR | | 100 | 100 | 1 | | | | | 7.8 | 8.4 |
| 9- 18 | | 0.6 | -- | 0.6 | | | | 7.5 | TR | | 100 | 100 | 1 | | | | | 7.8 | 8.3 |
| 18- 30 | | 0.7 | TR | 0.4 | | | | 7.1 | 1 | | 100 | 100 | 2 | | | | | 7.8 | 8.3 |
| 30- 42 | | 0.8 | -- | 0.3 | | | | 7.6 | TR | | 100 | 100 | 5 | | | | | 7.8 | 8.4 |
| 42- 58 | | 0.8 | TR | 0.3 | | | | 7.4 | TR | | 100 | 100 | 7 | | | | | 7.8 | 8.6 |
| 58- 78 | | 0.9 | TR | 0.3 | | | | 7.6 | 1 | | 100 | 100 | 6 | | | | | 7.8 | 8.7 |

Units for bases, acidity and CEC: MEQ / 100 G; base saturation and gypsum PCT.




Distribution of soil carbonate (inorganic carbon) at the global scale and in the Desert Project (Bottom), from Gile, et al. 2007. A 50th anniversary guidebook for the Desert Project. U.S. Dept. of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE. 279 p.

$$2CO_2 + H_2O + CaSiO_3 \rightarrow Ca^{++} + 2HCO_3^- + SiO_2$$
$$Ca^{++} + 2HCO_3^- \rightarrow CaCO_3 + CO_2 + H_2O$$

*Ebelmen-Urey Reaction*

$$\begin{array}{c} H_2O + CO_2 \\ \upharpoonleft\downharpoonright \\ CaCO_3 + H_2CO_3 \rightleftharpoons 2HCO_3^- + Ca^{++} \end{array}$$

*Dissolution-Reprecipitation Reaction*

# Workshop 2: Ecological Sites

**Workshop Summary**

We will discuss concepts for ecological sites, state-and-transition models (STM), and the kinds of data that can be collected to support soil-site correlation and STM development. Specifically, we will focus on the Sandy (MLRA 42.2) ecological site. The Sandy site has a rich source of data and is a relatively well-understood example of a fairly complex ecological site. Thus, it illustrates many of the issues and dynamics that will be observed in ecological sites across the U.S.

Specifically, we will discuss the following points:

- Soil-site correlation groups several similar soil map unit components within a single ecological site; to do otherwise would result in too many classes.

- Alternative states occur on similar soil profiles and thresholds separate these states. Thresholds are caused by feedbacks between biological and soil-surface processes that tend to produce large differences in ecological conditions.

- Any representative of a soil map unit component correlated to an ecological site will be observed in one of several states of the STM. Soil components correlated to an ecological site should be *capable* of existing in any of the states of its STM. Nonetheless, certain soil components *will more often* be observed in some states than others. This is because soil components exhibit gradational variation in soil climate at a regional scale and in properties that affect plant resource availability and therefore the likelihood of a transition to an alternative state.

- States are best regarded as being composed of patches that represent distinct functional units. Recognizing the proportions of patches can help visualize states in the field.

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*Note the patterns in the Google image (Quickbird satellite) and locations for the stops.*

Stop 1. Black grama grassland (reference state and reference phase).

Stop 2. Shrub-encroaching state A (black grama/bunchgrasses).

Vista 1. The "scrape site"; an experiment to measure what happens when all vegetation is removed from a Sandy soil.

Stop 3. Mesquite shrubland (incipient stage).

Stop 4. Shrub-encroaching state B (bunchgrasses; *Sporobolus flexuosus*, *S. contractus, Aristida purpurea*, *Eragrostis lehmanniana* [invasive], remnant *Bouteloua eriopoda*). Soil pit present.

# A. MLRA 42.2: Sandy Ecological Site

**Summary**

*Distinguishing soil features:* Loamy sand to sandy loam surface with a calcic or petrocalcic horizon and/or an argillic or cambic horizon featuring some clay increase with depth. Petrocalcic horizon, when present, is > 50 cm deep.

*Landscape features:* Sand sheets; relict basin floors, sand-buried piedmont slopes.

*Related ecological sites*: *Shallow sandy* has a petrocalcic horizon < 50 cm and *Deep sand* does not have a calcic, cambic, or argillic horizon. *Sandy* often exists as a fine mosaic with *Shallow Sandy*. Mesquite coppice dunes (torripsamments) are sometimes correlated to Deep sand (c.f. soil series in Hennessy et al. 1983b, 1985) but dunes actually represent a soil component of a state of the Sandy site.

*Dominant soil taxa*: Calciargids, Petrocalcids, Haplocalcids, Petroargids, Haplocambids, not shallow, usually coarse-loamy and non-gravelly.

*Common series*: Yucca, Harrisburg, Berino, Wink, Onite, Hueco, Nations, Pajarito, Pendero, Pintura, Rotura, Bucklebar, Cacique, Mohave.

*Reference state*: Historical plant communities were dominated by continuous black grama (*Bouteloua eriopoda*) mixed with other grasses, especially dropseeds (*Sporobolus* spp.). Representatives of the reference state are still common. Spatial variation in vegetation within the state may be governed by slight variations in soil texture of the A and/or B horizons within the site. For example, dropseeds may increase as soils become coarser. Continuous heavy grazing coupled to drought periods can lead to loss and fragmentation of black grama plants and increasing representation of dropseeds, threeawns (*Aristida* spp.), and snakeweed (*Gutierrezia sarothrae*) within this state. Black grama recovery is driven by recruitment from stolons into bare gaps. Scattered adult honey mesquite (*Prosopis glandulosa*) may be present.

*Transitions*: Year-long continuous grazing during multi-year periods of summer or spring drought can cause severe reduction, fragmentation, or total loss of black grama. Loss of black grama and increasingly large bare ground patches allow wind and water erosion. Feedbacks to grass mortality ensue. Recovery by stolons is increasingly difficult as black grama patches become isolated and inter-patch areas erode. Climatic conditions are seldom suitable for black grama recovery and establishment by seed is limited in this species. Concurrently, honey mesquite can be introduced (or is present) and expands due to one or more of the following processes; spread of seed by livestock, climatic events favorable to establishment, reduced competition for soil water, and reduced fire frequency. Continued heavy grazing on remnant grasses, perhaps exacerbated by native rodent and lagomorph herbivores and competition with shrubs, leads to loss of grasses in shrub interspaces, interspace erosion, and the formation of mesquite dunelands.

*Alternative states*:

Black grama-limited state: Black grama patches surrounded by a matrix of bunchgrasses/ subshrubs. During droughts, bunchgrass cover declines considerably leading to patchy erosion. Black grama does not recolonize eroded bunchgrass patches. Few adult mesquite.

Bunchgrass grassland: Black grama is absent or represented by a few relict plants. Sheet and wind erosion is common and continuous. Few adult mesquite.

Shrub encroaching/black grama: Black grama is usually patchy, mesquite are common with a mixed age structure or with many smaller mesquite suggesting a recent establishment event or ongoing recruitment and competition with grasses.

Shrub encroaching/bunchgrass: Bunchgrasses, subshrubs, or mesquite may be dominant; black grama may be present as a few isolated relict patches. Mesquite are common with a mixed age structure or with many smaller mesquite suggesting recent establishment or ongoing recruitment. Mesquite cover may be high, but loss of soil from shrub interspaces is moderate.

Mesquite shrubland: Mesquite are dominant with significant coppicing around shrubs and deflation in shrub interspaces. Soil loss and redistribution is significant.

*Patch types composing states:*

Black grama (stoloniferous grass): Often densely vegetated with small interspaces and persistent in drought if minimally disturbed by grazing; accumulates soil deposits (usually has a thin C horizon); may have abundant BSCs. May include scattered *Ephedra* and *Yucca*.

Bunchgrass/subshrub: Densely to sparsely vegetated often with large interspaces, soil surface often moderately eroded and with platy structure. May include scattered *Ephedra* and *Yucca*.

Lehmann's lovegrass (invasive/fire-tolerant): Densely vegetated, often intermixed with bunchgrasses on moderately eroded soils, similar to bunchgrass patch.

Barren/ephemeral forb: Sparsely to non-vegetated, often observed with *Croton* after rains. Moderately to deeply eroded, platy soils

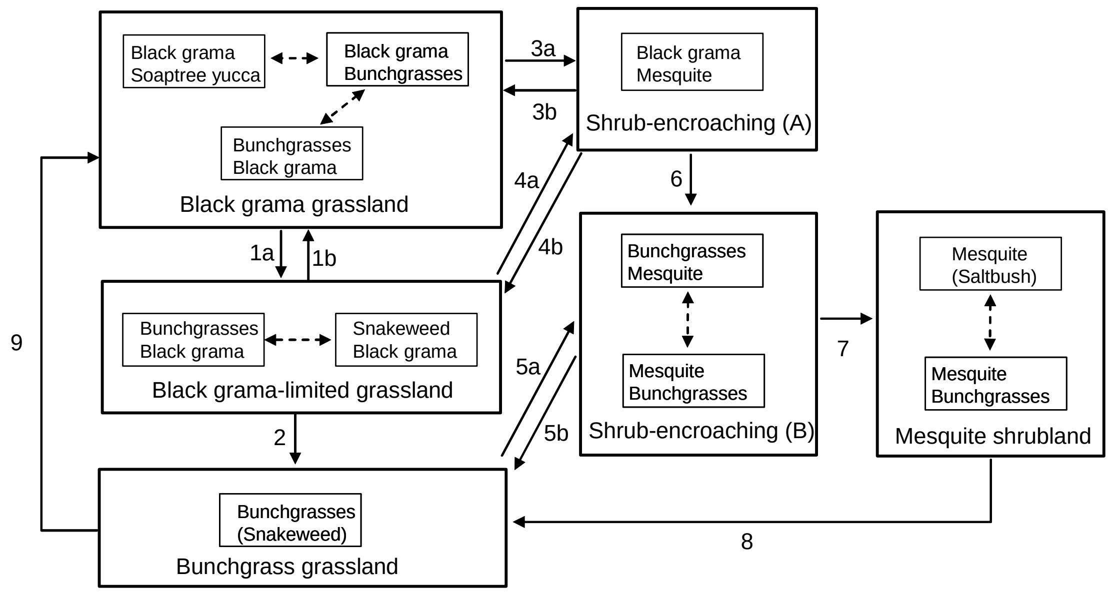
Barren/eroded: Usually non-vegetated with a hard, often cemented, subsoil exposed at the surface that may be overlain with thin sheets of sorted sand.

Mesquite/non-buried: Mesquite plant and area below its canopy, often featuring a thin O horizon and grasses such as *Setaria leucopila*. Often associated with high levels of pedoturbation by rodents.

Coppice dune/mesquite: Mesquite plant and accumulated soil deposits forming a thick C horizon. Litter abundant. Coppice may harbor other shrubs (*Atriplex*) and bunchgrasses.

*Restoration*: Restoration from mesquite shrubland and shrub-dominated states has generally been unsuccessful. Use of herbicide within shrub-encroaching states is believed to have promoted persistence of grass cover, although shrub regrowth is generally observed (i.e., these states are resilient). Black grama recovery within black grama-limited and bunchgrass states has not been observed, although recent high-rainfall years have led to increases in black grama cover within these and shrub-encroaching states.

State-Transition model: MLRA 42.2; Upland sandy site group: Sandy




**1a**. Grazing in drought periods, black grama fragmentation. **1b.** Unknown, possible role for extreme wet periods
**2**. Black grama extinction due to heavy grazing in drought, soil erosion.
**3a**. Mesquite seed introduction with black grama fragmentation, lack of fire. **3b**.Shrub removal
**4a**, **5a**. Mesquite seed introduction or mesquite release from biological constraint. **4b**, **5b**. Shrub removal
**6**. Heavy grazing, drought causes black grama extinction, greater opportunities for mesquite expansion, wind erosion/deposition from adjacent shrublands
**7**. Heavy grazing or ORV disturbance, bunchgrass loss, wind/sheet erosion, soil truncation
**8**. Mesquite removal coupled to soil stabilization, nutrient addition, seeding during wet periods.
**9**. Unknown, possibly via reseeding in extreme wet periods

## Black-grama dominated state

- Black grama, soaptree yucca, dropseeds threeawns. No mesquite in immediate area.
- Black grama cover and stature is high
- Small patches of bare ground, covered with litter and BSCs.
- Berino-Buckelbar map unit, Jornada Experimental Range, Dona Ana Co.

## Black grama-limited state

- Black grama, threeawns, snakeweed, few mesquite.
- Black grama cover and stature is low
- Large patches of bare ground, unprotected by litter and eroding.
- Wink-Harrisburg map unit, Jornada Experimental Range, Dona Ana Co.

## Shrub encroaching state A

- Black grama common, but fragmented
- Several size classes of mesquite
- High bare ground cover despite recent high rainfall, moderate erosion.
- Berino taxadjunct, CDRRC, Dona Ana Co.

## Shrub-encroaching state B

- Snakeweed, some threeawns, many mesquite
- Grass cover very low, no black grama
- Note evidence of wind erosion, litter accumulations in small depressions
- Wink Harrisburg map unit, Dona Ana Co.

## Mesquite shrubland state (advanced)

- Mesquite, some snakeweed
- No grass cover in interdunes, some dropseeds associated with mesquite coppices
- Soil surface indurated and rich in carbonate, exposed roots.
- Copia-Nations complex,Fort Bliss, Otero Co.

**Catalog of states and community pathways**

*Black grama grassland*: The reference plant community is dominated by black grama. Dropseeds (*Sporobolus flexuosus, S. cryptandrus,* and *S. contractus*) are often secondary dominants, intermixed with black grama or occurring as discrete patches. Bush muhly (*Muhlenbergia porteri*) and threeawns (*Aristida* spp.) are other common grasses. Soaptree yucca (*Yucca elata*), longleaf ephedra (*Ephedra trifurca*), and sand sage (*Artemisia filifolia*) are common shrubs. Scattered, adult mesquite (*Prosopis glandulosa*) can be present. This state is defined by the capacity of black grama to persist indefinitely (e.g. some permanent quadrats on the Jornada Experimental Range). The caespitose, bushy growth form of black grama cover stabilizes the sandy soil surface, leading to low erosion rates relative to the cover of other bunchgrasses (Paulsen and Ares 1962). Soil stability is sometimes reflected in biological soil crusts that proliferate in bare interspaces surrounded by black grama. Extensive black grama grasslands are believed to have established during the Little Ice Age, the most recent minimum of which was in the mid-1800s. Currently, black grama grasslands are sustained by vegetative reproduction (often from stolons) into small (usually <50 cm) bare interspaces. Reproduction by seeding is believed to be rare under current climate (Jackson 1928, Nielson 1986) so black grama grasslands are sometimes considered relict vegetation (in MLRA 42.2) in which mortality typically outpaces reproduction. Mesquite establishment within this state is not significant. Fires may or may not be an important reason for low mesquite recruitment and it is not clear why mesquite recruitment is limited.

Black grama plants maintain carbohydrates in their tillers and stolons (vegetative reproduction structures) above ground throughout the winter (Miller and Donart 1979). Thus, this species is preferred in winter months and declines with increasing stocking rates (Holechek et al., 1994). In addition, black grama's dominant mode of local colonization is via stolons and stolon establishment is vulnerable to trampling and drought (Nelson 1934, Wright and Van Dyne 1976). Heavy grazing results in an increasing relative cover of dropseeds, threeawns, or snakeweed. It is also possible that in coarser soils, such as loamy sands, dropseeds tends to exhibit high cover relative to black grama irrespective of grazing pressure. Two seasons without summer rains will also lead to black grama decline (Robert P. Gibbens, personal communication). Grasses such as dropseeds and threeawns are thought to be more sensitive to drought than black grama (Herbel et al. 1972) but can recover more rapidly via seeding. Snakeweed or dropseeds may become dominant within this state due to grazing effects as long as the capacity of black grama to recover after cessation of grazing is not compromised. An even distribution of black grama plants capable of reoccupying areas between plants via stolon-based reproduction is suspected to be a prerequisite for resilience of this state. Gibbens and Beck (1987) and some unpublished records from the USDA-ARS Jornada Experimental Range, Las Cruces, NM provide evidence for recovery of black grama from dropseed dominance at a local scale (1 $m^2$). Campbell and Bombarger (1934) indicate that black grama can recover in areas dominated by subshrubs such as snakeweed (*Gutierrezia sarothrae*).

<u>Diagnosis</u>: Black grama is dominant and/or cover is continuous, canopy can exceed 60%. There is evidence of black grama reproduction by stolons. Large basal gaps (> 2 m) are typically not more than 30% of line, gaps often covered with biological soil crusts. Pedoderm Class = WP or PDB; Resource Retention Class = 1-2; Soil Redistribution Class = 0-2. Litter cover is abundant. Soil stability values range from 4-6. There are no mesquite or a few, scattered adult individuals (< 1% cover).

**Transition to black-grama limited state (1a)**: Disturbance and death of black grama plants across large areas (due to grazing and trampling), possibly in concert with climate change, is the trigger of the transition. Once black grama plants are reduced to widely-scattered patches they are incapable of reestablishing dominance via vegetative reproduction (the threshold). Subsequent loss of soil fertility by moderate erosion may contribute to the threshold and the persistence of the black grama-limited state. Wright and Van Dyne (1976) noted that the effects of cattle trampling may be more important than the effects of grazing per se. Furthermore, those authors found an effect of grazing on only loamy sands suggesting that relatively minor variations in soil texture may determine the sensitivity of black grama to grazing. Herrick et al. (2002) suggest that loss of litter cover, plant cover, and perhaps biological soil crusts leads to soil degradation that creates an unfavorable environment for black grama. In particular, the loss of soil carbon that maintains microbial populations and soil moisture at rooting depth may be an important mechanism (Jerry Barrow, personal communication). Increases in threeawns seem to be an especially ominous indicator of a transition, although it is unclear why. According to the review by Howard (1987), *Aristida purpurea* is favored by winter-spring precipitation, is animal dispersed, is disturbance-adapted, and is usually unpalatable. Thus, the variety of processes postulated to reduce black grama may all favor this grass.

<u>Key indicators of approach to threshold</u>: Increases in bare ground, decreases in litter cover and black grama cover, increasing distance between black grama plants, decreased soil surface resistance to erosion, decreases in soil organic matter, increases in disturbance-adapted grass species (including threeawns and fluffgrass [*Dasyochloa pulchella*]).

**Transition to the shrub-encroaching state (3a):** Fragmentation of black grama can co-occur with accelerating establishment of mesquite shrubs. Some investigators believe that shrub invasion is facilitated by reductions in black grama (i.e., the trigger). On the contrary, Herbel and Gibbens (1996) suggest that mesquite expansion can occur within apparently intact black grama stands. It is possible that the latter pattern emerges when the propagule load to an intact site is very high due its proximity to adjacent mesquite-dominated areas. Alternatively, mesquite propagules are typically present as seeds but are able to achieve maturity in the absence of fire. If the competition hypothesis is true, selective herbivory on black grama with continued grazing promotes establishment of mesquite. If the fire hypothesis is true, then the reduction of fire frequency associated with the loss of fine fuels promotes mesquite establishment. If the small animal shrub herbivory hypothesis is true, then the elimination or reduction of mesquite seedling predators promotes mesquite establishment, independent of grass cover. If the dispersal hypothesis is true, then once introduced, mesquite may expand despite cessation of grazing. It is likely that several of these processes work in parallel or in different instances. Widespread establishment of mesquite within fragmented, black grama grasslands constitutes a threshold because mesquite are unlikely to die over a management timeframe.

<u>Key indicators of approach to threshold</u>: Same as for transition 1a if the competition hypothesis is true. If the fire hypothesis is true then a reduction of black grama annual production and litter cover are indicators. If the dispersal hypothesis is true then there are no suitable indicators, other than the presence of potential seed vectors (i.e. livestock) and their connection to a seed source (a mesquite-invaded area).

*Black grama-limited grassland state*: Black grama has been reduced to a subordinate component of the plant community and dropseeds and threeawns dominate. Black grama often exists as discrete, widely-distributed patches in a matrix of bunchgrasses and subshrubs exhibiting substantial bare ground cover and high connectivity. Evidence of erosion is common, larger black grama patches are often elevated by several inches relative to the surrounding matrix. Snakeweed may achieve dominance for long periods because it is less palatable than the grasses. Furthermore, once snakeweed attains a high density, some feel that allelopathic (Tirmenstein 1999) or competitive effects may inhibit the growth of grass populations. Jameson (1970), however, failed to document any competitive suppression of snakeweed on black grama. Climate (Campbell and Bombarger 1934), fire (McDaniel et al. 2000) and beetle herbivory (*Crossidius* spp.; Thompson et al. 1996) may regulate patterns of snakeweed abundance. Because snakeweed is a cool-season plant, it tends to increase in response to increases in winter-spring precipitation.

It is not clear why black grama does not recover over long time periods. It is possible that the rate of expansion of remnant black grama patches is very slow and tiller establishment from stolons is difficult in large, bare interspaces. Reduced soil quality due to erosion and loss of soil organic matter in large bare interspaces, unfavorable microclimate (high heat, low soil moisture), or rodent/lagomorph herbivory on grasses at patch edges may contribute to this limitation.

Following the drought of the 1950s, black grama basal cover increased from 1957-1977 on the Jornada Experimental Range but dropseeds often increased at a greater rate and became dominant or co-dominant (Herbel and Gibbens 1996). This pattern may be consistent with black grama reproductive limitation in this state. In either black grama or bunchgrass (snakeweed)-dominated communities, soil stability may be considerably lower than in the black-grama dominated grassland state.

<u>Diagnosis</u>: Black grama cover is fragmented and canopy cover is lower than that of bunchgrasses. Black grama often occurs as discrete patches. Mesquite plants are uncommon. Evidence of erosion is common, including pedestalled plants, water flow patterns, and small blowouts. Pedoderm Class = WP; Resource Retention Class = 3-4; Soil Redistribution Class = 2-3.

**Transition to bunchgrass grassland state (2)**: The local extinction of black grama is caused by heavy grazing in combination with drought.

<u>Key indicators of approach to threshold</u>: Fragmentation of remnant black grama patches, decadence of remnant black grama plants, pedestalling or sand burial of black grama plants, lack of black grama reproduction (stolon production).

**Transition to shrub-encroaching state (4a)**: Accelerated mesquite establishment may occur years after black grama reproduction has become limited and/or black grama dominance declines. Environmental conditions are likely to be suitable for mesquite establishment within the black-grama limited state. Thus, only the presence of a mesquite-seed vector or climatic conditions favorable for establishment is required for this transition to take place.

<u>Key indicators of approach to threshold</u>: There are no suitable indicators, other than the presence of potential seed vectors (i.e. livestock) and their connection to a seed source (a mesquite-invaded area).

**Restoration to black grama grassland state (1b)**: Black grama has been observed to survive in certain patches on the Jornada Experimental Range through the drought periods (R. P. Gibbens, personal communication). Understanding what properties distinguish these patches from areas where black grama has declined may hold important clues to preventing grassland degradation and restoring black grama. Methods for reversing the transition are currently unknown. It is possible that black grama patches could expand via vegetative (stolon) reproduction to reoccupy a site during a multi-year period of high summer rainfall over several decades.

*Bunchgrass grassland state*: This state is characterized dominance by bunchgrasses (threeawns or dropseeds) or snakeweed. Lehman's lovegrass (*Eragrostis lehmanniana*) has recently begun to increase in abundance within representatives of this state. Black grama is absent or represented by very few relict patches. Mesquite are present but are uncommon. Erosion by wind and water may be significant in this state. The absence of black grama leads to large fluctuations in grass cover between high and low rainfall periods as bunchgrasses die off and reestablish.

Diagnosis: Absence of black grama plants or a few scattered individuals. Canopy cover is highly variable. Mesquite is uncommon. Pedoderm Class = WP; Resource Retention Class = 3-5; Soil Redistribution Class = 3.

**Transition to shrub-dominated state (5a)**: Similar to 4a. Bunchgrass cover is highly variable, so shrubs often dominate the aspect and function of the site once they spread.

**Restoration to black grama grassland state (9)**: Intensive restoration (e.g., re-seeding, re-planting) techniques are not known to be successful or practical. Climatic conditions would need to be suitable for seed production in adjacent areas and establishment from seed.

*Shrub-encroaching states (A and B)*: Mesquite recruitment is common and many young mesquite are present. On soils with > 5% gravel content, some creosotebush (*Larrea tridentata*) may expand as well. In some cases, accelerating mesquite establishment occurs in continuous or patchy black grama grassland (*Shrub-encroaching/black grama state A*). In other cases, mesquite expands after significant black grama degradation has already occurred and bunchgrasses are dominant (*Shrub-encroaching/bunchgrass state B*). It is believed that black grama loss (**transition 6**) and increases in shrub density eventually occur unless grazing rest and/or shrub control is applied (e.g. Hennessy et al. 1983b). Where mesquite densities are highest (>20% canopy cover), black grama tends to absent (*Shrub-encroaching/bunchgrass state B).*

Mesquite plants may be very small and difficult to detect with casual observation. Although fire may kill small (< 1.5 yr old; Wright et al. 1976) mesquite, it is unlikely that fire return intervals are sufficiently short to remove mesquite from a grassland if mesquite seed flow to a grassland is significant. Livestock and native animals, particularly coyotes (*Canis latrans*), are common vectors of viable mesquite seeds (Kramp et al., 1998). Thus, it is likely that mesquite seedlings are a normal component of black-grama-dominated grassland but are suppressed by fire, small mammal herbivory, and/or competition in the black grama-dominated state (Brown and Archer 1999). Areas of high mesquite density tend to exhibit fragmentation of black grama grass due to competition, heavy grazing, or rodent herbivory. There are no data available, however, that relate grass reproduction to levels of invasion. Valentine (1936), however, indicates that beyond a height of 1-2 feet, mesquite begins to exclude grasses from around plant bases. Mesquites may provide cover and nest sites for rodents (e.g. kangaroo rats) and lagomorphs (jackrabbits, cottontails) that increase herbivory on black grama adults and seedlings (Campbell 1929, Bestelmeyer et al., 2007). If black grama reproduction is limited, it may be rapidly extirpated with grazing and interactions with shrubs and only bunchgrasses may remain to stabilize soils (**transition 6**).

Within shrub-encroaching state B, bunchgrass cover can be highly variable. Depending on shrub density, herbaceous production may exceed shrub cover in wet years whereas in other years shrubs and subshrubs such as snakeweed are clearly dominant. Shrub canopy cover may exceed 40% but coexist with a substantial cover of bunchgrasses (10%). We do not understand the causes of variation in grass and shrub densities within this state.

Within this state, brush control using herbicides (e.g. 2,4,5-T) resulting in at least a 30% mesquite kill can result in increases in grasses (Herbel et al. 1983). Gibbens et al. (1992) suggests that the duration of mesquite suppression typically lasts 20-30 years before mesquite densities return to (or surpass) pre-treatment levels. It is therefore valid to regard herbicide use within the shrub-encroaching states as within-state management, rather than restoration to grassland.

Diagnosis: Mesquite are common and usually conspicuous. Many small mesquite indicate recent recruitment and a recent transition to this state. Black grama cover is substantial, but often fragmented by bare ground, in Shrub-encroaching state A. Bunchgrasses may be dominant or sparse, depending on recent climate, in Shrub-encroaching state B. Canopy cover and indicator values are highly variable.

**Restoration to black grama grassland, black grama-limited, or bunchgrass grassland states (3b, 4b, 5b)**: Mesquite removal via herbicide use (typically via clopyralid and triclopyror) or physical means in the early phases of mesquite establishment might be able to circumvent (or significantly delay) mesquite expansion. Mesquite removal coupled with high grass cover could be used to shorten fire return intervals and control mesquite if fire governs grassland resilience. The successful use of fire in black grama grasslands, however, depends strongly upon the size of mesquite and probably on post-fire precipitation patterns that favor black grama recovery (Drewa and Havstad 2001). At this point, it is unclear if fire can be effectively used as a management tool to promote black grama dominance. Increased black grama cover following mesquite removal and high rainfall years might preclude mesquite recovery via competition, although this has not been observed. Neither fire nor competition is likely to keep mesquite from recovering in black-grama limited or bunchgrass grassland cover levels. If climate or mesquite seed availability alone is responsible for transitions 3a, 4a, or 5a, transitions to grasslands may be impossible.

**Transition to mesquite shrubland state (7):** Fragmentation or loss of remaining interspace plant cover due to heavy grazing and/or drought leads to increasing erosion and redistribution of soil to shrubs (Schlesinger et al., 1990) or out of the site (Gillette and Monger 2006). Erosion leads to loss of remaining grasses due to soil destabilization, exacerbated by increasingly concentrated rodent and livestock herbivory on grasses. The factors responsible for the apparently great variation in the occurrence of this transition are unknown. Variation in landscape position and soils currently correlated to this site may be responsible. Soils with well-developed clay-rich horizons tend to form hardpans after erosion and soil truncation. Soils without strongly contrasting horizons may retain the capacity to support grasses (usually dropseeds) even after erosion. In some rare instances, as yet not understood, perennial grasses and mesquite may coexist within the shrub encroaching state with high cover values (e.g., both > 10% canopy cover) with no apparent progress to mesquite duneland.

Key indicators of approach to threshold: Continued loss of grass cover, evidence of increased bare ground and connectivity of bare ground, and evidence of wind and sheet erosion (e.g. pedestalling, blowouts, or the accumulation of caliche chunks and stones at the surface).

*Mesquite shrubland*: Mesquite are dominant and intershrub areas are typically eroded with a sparse vegetation cover of annual plants and subshrubs. Wind-eroded soil accumulates on mesquite to form coppice dunes (or *nabkas*; Langford 2000) over time. Perennial grasses, restricted to bunchgrasses, may be observed only during the wettest periods. In other periods, grasses cannot colonize interdunes due to the instability of the substrate, high soil surface temperatures (Hennessy et al. 1985), or low nutrient availability. Rodent and rabbit herbivory on grass seedlings may be important where other physical factors are not limiting. In some cases, mesquite does not dominate and erosion to B horizons (e.g. sandy clay loams) leads to dominance by snakeweed and saltbush (*Atriplex canescens*). In some cases, soil truncation exposes clay- and carbonate-rich subsoil that is very hard and does not permit plant establishment.

Differential mortality or recruitment and growth of mesquite shrubs occur in response in wind erosion, leading to the formation of "mesquite streets" oriented in the direction of erosive winds (Gillette et al., 2006, McGlynn and Okin 2006). The mesquite streets are especially hostile for vegetation establishment due to sand abrasion and deposition. Thus, even though mesquite interdune soils have not been shown to exhibit reduced plant-available soil water (Herbel and Gibbens 1987, Hennessy et al. 1985) or a loss of organic matter (Hennessy et al. 1985) relative to a grassland state, erosion processes may constrain grass recovery. Herbivory by native mammals may also be an important constraint.

Coppice soils are more or less homogenous to depths of a meter or more and are often classified as Pintura or Copia soil series. This soil classification has prompted some investigators to refer to these dunes as Deep sand ecological sites. Deep sand sites occur naturally and support a distinct plant community, so it is preferable to consider recently-formed coppice dunes as a soil element of the mesquite shrubland state. Perennial grasses and other shrubs, especially saltbush, can colonize dune soils because of the greater availability of water there (Hennessy et al. 1985).

<u>Diagnosis</u>: Mesquite is dominant. Coppice dunes from over time, and range from 0.5-3 m high (depending on age and depth to caliche). Bunchgrasses are usually rare or absent; when present they are often restricted to coppice dunes. In extremely wet years, dropseeds may colonize interdunes where impermeable horizons have not been exposed. There is often evidence of wind erosion and deposition including extreme pedestalling, plant burial, highly sorted sand, ripples, and an exposed B horizon in interdunes. Pedoderm Class = S, SP, or CEM; Resource Retention Class = 5; Soil Redistribution Class = 4b.

**Transition to bunchgrass grassland (8):** In principle, it may be possible to kill mesquite, redistribute or add soil nutrients, and stabilize soil during periods favorable to the germination of bunchgrasses, perhaps in conjunction with seeding. The use of municipal biosolids may aid in restoring soil fertility (Walton et al. 2001).

## B. Three tiers of data collection

*Tier 1: Low-intensity, extensive survey (traverse)*

- Explore relationships among states, soils, landforms, climate, and land-uses across the MLRA or LRU.
- Develop or rapidly verify ecological site and state concepts
- Rapid soil, plant, and indicator collection (30 minutes) at arbitrary or stratified-random points

*Tier 2: Medium-intensity inventory (transecting or stratified inventory)*

- Develop quantitative statistical relationships between the properties of states and soils/landforms across a broad extent.
- Quantitative descriptions of state-soil relationships across the MLRA or LRU at stratified-random points
- Plant cover estimated ocularly or measured precisely; soil mini-pit characterized (1-2 hours).

*Tier 3: High intensity characterization*

- Detailed quantification of vegetation, pedoderm, and soil profile properties for representatives of alternative states, particularly the reference state.
- Allows tests of resilience mechanisms postulated in STMs and allows properties to be generalized via maps of states.
- Plant cover via line-point intercept, production, dynamic soil properties, soil pit at random points within state units or within carefully-selected representatives (several hours).

## C. Forms used for Tier 1 and Tier 2 data collection

In the pages that follow we offer a “Pedoderm and Pattern Class” form developed for Tier 2 use. In addition, we use a Soil form to characterize the soil profile and a Plant Data form in Tier 2. These are available at http://usda-ars.nmsu.edu/esd/esdResources.html. Finally, we present an example of the Tier 1 “ESD Traverse” form, which we will use in the field.

# ESD Pedoderm and Pattern Classes (assessed for ___ x ___m plot)

| | | | | |
|---|---|---|---|---|
| Site: | Plot: | State & Co: | MLRA: | LRU: |
| Investigators: | Date: | Location: | | |
| UTM Datum & Zone: | Easting: | Northing: | Elev: m or ft | SMU: |

***Pedoderm Class in ___ x ___ m***

| | select one | [1]Dom Biol Crust or VC | **Notes** |
|---|---|---|---|
| S = Soil; pedoderm is characterized by bare mineral soil and none of the classes below. | | | |
| SA = Well-formed or distinct structural aggregates at the soil surface and no other class below (well aggregated, stable soils). | | | |
| WP = Weak physical or biological crust; can be disrupted by rainfall, none to few cyanobacterial sheaths dangling from ped, no darkening from cyanobacteria. | | | |
| SP = Strong physical crust; usually platy or massive (structure not disrupted by rainfall), no substantial biological component. | | | |
| CEM = Cemented pan exposed at surface | | | |
| SC = Salt crust of fine to extremely coarse evaporite crystals or visible whitening on the soil surface; may include biological components. | | | |
| PDB = Poorly developed biological crust assemblage, many cyanobacterial sheaths, may be slightly dark, can include other functional/structural groups (algae, lichen, moss).[1] | | | |
| SDB = Strongly developed biological crust assemblage, obvious dark cyanobacteria, rubbery algal, moss or lichen crust.[1] | | | |
| CB = Cracking or curling, rubbery algal crusts, with or without lichen.[1] | | | |
| EP = Erosion pavement; a concentration of rock fragments at the soil surface caused by erosion and removal of finer soil material; individual fragments may be displaced during runoff events. | | | |
| DP = Desert pavement; a concentration of closely packed and polished rock fragments at the soil surface, embedded in a vesicular crust. | | | |
| D = Duff; partially and fully decomposed plant & organic matter; above the A horizon. | | | |

[1] List 1-2 dominant biological crust functional structural groups from this list: Cyano (Cyanobacteria), LC (Lichen Crust), M (Moss), LV (Liverwort), A (Algae). Vesicular crusts (VC) should be noted when present

***Resource Retention Class in ___ x ___ m*** (choose one)

| | cm | **Notes:** |
|---|---|---|
| 1. Interconnected grass cover or dense bunchgrasses and surrounding round bare patches <30cm | | |
| 2. Grass cover interconnected and surrounding round/oval bare patches 30-___cm across | | |
| 3. Grass cover fragmented by elongate bare areas to ___ cm wide but bounded in plot | | |
| 4. Grass cover fragmented by elongate bare areas to ___ cm wide that cross through the plot | | |
| 5. Bare ground interconnected in several directions and isolated grass patches up to ___ cm | | |
| 6. Bare ground interconnected with scattered or no grass plants | | |

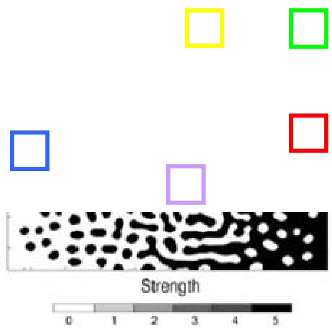
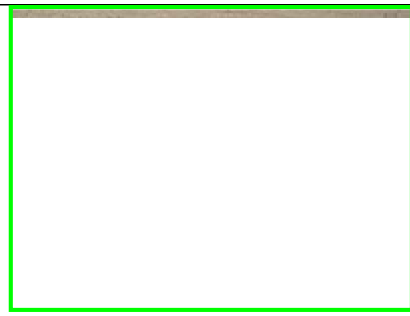
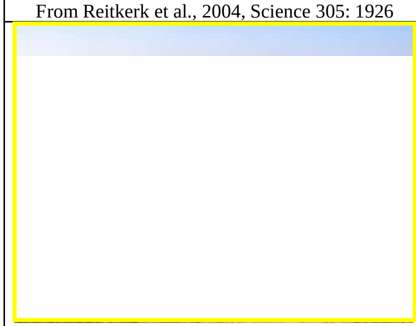
***Soil Redistribution Class in ___ x ___ m*** (check erosion and/or deposition observed)

| | **Eros** | **Depo** | **Notes:** |
|---|---|---|---|
| 0. No evidence of erosion or deposition. | | | |
| 1. Minor soil redistribution. | | | |
| 2. Patchy soil loss and deposition[2]. | | | |
| 3. Moderate soil loss across the plot and patchy sediment deposition. | | | |
| 4. Extensive, deep soil loss and/or deep deposition[3]. | | | |
| a. Erosion with exposed subsoil (little deposition). | | | |
| b. Erosion with exposed subsoil coupled with patchy sediment deposition. | | | |
| c. Extensive sediment deposition. | | | |

[2] Depositional mounds are formed by the settling of sediment transported by wind and/or water movement; mounds can occur on or behind obstructions to flow or where flow speeds are reduced.

[3] Confirm deposition within a soil pit. Recently deposited material is usually seen as a thinly or finely stratified soil surface with alternating thin layers of varying textures; lacks structure.

## *Resource Retention Class Guide*

| | | |
|---|---|---|
|   From Reitkerk et al., 2004, Science 305: 1926 |  1. Interconnected grass cover or dense bunchgrasses; and surrounding bare patches <30cm |  2. Grass cover interconnected and surrounding round bare patches from 30-___cm |
|  3. Grass cover fragmented by elongate bare areas to ___ cm wide but bounded in plot |  4. Grass cover fragmented by elongate bare areas to ___ cm wide that cross entire width of plot |  5. Bare ground interconnected in several directions and isolated grass patches up to ___ cm |

### *Soil Redistribution Class Definitions*

0. **No evidence of erosion or deposition**.

1. **Minor soil redistribution**. Evidence includes narrow, elongate, sometimes tortuous, water flow patterns, and litter movement indicating loss of thin soil layers and thin soil deposits from wind or water. No noticeable thinning of the A horizon and soil movement occurs within a matrix of vegetated/stable soil.

2. **Patchy soil loss and deposition.** Evidence includes small pedestals, soil lines on rock fragments, terracettes, water flow patterns, litter dams, wind scouring, small (e.g., < 10 cm tall) depositional mounds[1]. A horizon thinned in discrete patches within a matrix of vegetated/stable soil. Note approximate size of eroded patches. Sediment source may be on or off of the plot.

3. **Moderate soil loss across the plot and patchy sediment deposition**. Evidence includes prominent pedestals, soil lines on rock fragments, gravel lag, water flow patterns, rills, and depositional mounds suggesting significant soil loss and/or deposition from eroded areas. Noticeable thinning of A horizon across plot with patches of stable/vegetated soil and patchy sediment deposits. Sediment source may be on or off of the plot.

4. **Extensive, deep soil loss and/or deep deposition**. Evidence includes scarps/scarplets, prominent pedestals, rills, gullies, extensive wind scouring, exposed roots, large (e.g., > 20 cm tall) depositional mounds, and buried plants indicating substantial deposition[2]. A plot is often embedded in an extensive area of erosion and deposition and expresses one of the following (choose only one below):

a. *Erosion with exposed subsoil (little deposition)* . Prominent pedestals, often with decadent or dead plants, and rills/gullies exposing subsoil horizons. Usually associated with fluvial processes.

b. *Erosion with exposed subsoil coupled with patchy sediment deposition.* As above and includes sediment accumulation (e.g., coppice dunes) intermixed with areas of eroded soil. Usually associated with a mix of fluvial and eolian processes.

c. *Extensive sediment deposition* . Sediment sheets continuous across plot, usually indicated by buried plants/stones or hummocky surface. May be hard to detect without excavation. Sediments originate from outside of the plot. Rills may be present. Associated with fluvial or eolian processes.

# ESD Traverse Data Form

| | | | | |
|---|---|---|---|---|
| Site: | State: | County: | MLRA: | LRU: |
| Investigators: | Date: | Location: | | |

| WP | Elev | Slope (%) | Aspect ( ° ) | Top depth (cm) | Bot-tom depth (cm) | % GR | Texture or Horizon | Eff | Ecological Site | List Dominant Plants in Order | Cover class | Dom Shrub/ Tree Ht. | Pedoderm Class | Resource Retention Class | Soil Redistri-bution Class | State / Plant Community | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 1 | | | | | | | |
| | | | | | | | | | | 2 | | | | | | | |
| | | | | | | | | | | 3 | | | | | | | |
| | | | | | | | | | | 4 | | | | | | | |
| | | | | | | | | | | 5 | | | | ____ cm | | | |
| | | | | | | | | | | 1 | | | | | | | |
| | | | | | | | | | | 2 | | | | | | | |
| | | | | | | | | | | 3 | | | | | | | |
| | | | | | | | | | | 4 | | | | | | | |
| | | | | | | | | | | 5 | | | | ____ cm | | | |
| | | | | | | | | | | 1 | | | | | | | |
| | | | | | | | | | | 2 | | | | | | | |
| | | | | | | | | | | 3 | | | | | | | |
| | | | | | | | | | | 4 | | | | | | | |
| | | | | | | | | | | 5 | | | | ____ cm | | | |
| | | | | | | | | | | 1 | | | | | | | |
| | | | | | | | | | | 2 | | | | | | | |
| | | | | | | | | | | 3 | | | | | | | |
| | | | | | | | | | | 4 | | | | | | | |
| | | | | | | | | | | 5 | | | | ____ cm | | | |
| | | | | | | | | | | 1 | | | | | | | |
| | | | | | | | | | | 2 | | | | | | | |
| | | | | | | | | | | 3 | | | | | | | |
| | | | | | | | | | | 4 | | | | | | | |
| | | | | | | | | | | 5 | | | | ____ cm | | | |
| | | | | | | | | | | 1 | | | | | | | |
| | | | | | | | | | | 2 | | | | | | | |
| | | | | | | | | | | 3 | | | | | | | |
| | | | | | | | | | | 4 | | | | | | | |
| | | | | | | | | | | 5 | | | | ____ cm | | | |

# References for Workshops 2 and 3

**An abbreviated ecological site description is provided. For a complete description: http://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD**

## ECOLOGICAL SITE DESCRIPTION

### ECOLOGICAL SITE CHARACTERISTICS

**Site Type:** Rangeland

**Site Name:** Sandy

**Site ID:** R042XB012NM

**Major Land Resource Area:** 042 - Southern Desertic Basins, Plains, and Mountains

**Physiographic Features**
This upland site occurs on alluvial fans, fan piedmonts, fan remnants or fan terraces between the foothills of mountains and the floodplains. These fans are often dissected by small arroyos. Slopes range from 1 to 8 percent. It occurs on all exposures. Elevations range from about 4,500 feet above sea level to 5,500 feet.

**Climatic Features**
This site has an arid climate with distinct seasonal temperature variations and large annual and diurnal temperature changes characteristic of a continental climate. Precipitation averages 8 to 10 inches annually. Deviations of 4 inches or more from the average are quite common. Fifty percent of the precipitation is received from July to November, which is the dominant growing season of native plants. Summer precipitation is characterized by high-intensity, short-duration rainstorms. Winter precipitation averages less than one-half inch per month, usually in the form of rain. There are occasional snowstorms of short duration. Temperatures vary from a mean monthly average of 77 F in July to 34 F in January, with a maximum of 104 F and a minimum of -10 F. The average last killing frost in the spring is April 15 and the average first killing frost in the fall is October 28. Frost-free season averages 185 days. Temperatures are conducive to native grass and forb growth from March through November. Spring winds of 15 to 40 miles per hour are common from February to June.

**Influencing Water Features**

**Representative Soil Features**
These soils are deep to moderately deep. The surface textures are sandy loam, gravelly sandy loam, gravelly fine sandy loam, fine sandy loam, gravelly loamy fine sand. The subsoil textures are sandy clay loam, sandy loam, gravelly loam, or gravelly sandy loam. The substrata are loamy fine sand, fine sandy loam, very cobbly loam, gravelly sandy loam, or gravelly loamy sand. The soils are usually calcareous throughout.

**Plant Communities**
*See Workshop 2 and 3*

**Ecological Dynamics of the Site**
*See Workshop 2*

**Ecological Site Interpretations** (animals, hydrology, recreation, products)

**Supporting Information** (associated and similar sites, references, approvals)

## Stop 1

### *** Primary Characterization Data ***

( Dona Ana, New Mexico )

Pedon ID: S01NM-013-001

Print Date: Apr 22 2009 12:18PM

Sampled As : Jer1

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 01N0517

| PSDA & Rock Fragments | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- | -12- | -13- | -14- | -15- | -16- | -17- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (- - - - - Total - - - - - -) | | | (- - Clay - - -) | | (- - - - Silt - - - - -) | | (- - - - - - - - - - - - - Sand - - - - - - - - - - - - -) | | | | | ( Rock Fragments (mm) ) | | | | |
| | | | | Clay | Silt | Sand | Fine | $CO_3$ | Fine | Coarse | VF | F | M | C | VC | (- - - - - - - - - Weight - - - - - - - - -) | | | | >2 mm |
| | | | | < | .002 | .05 | < | < | .002 | .02 | .05 | .10 | .25 | .5 | 1 | 2 | 5 | 20 | .1- | wt % |
| | Depth | | | .002 | -.05 | -2 | .0002 | .002 | -.02 | -.05 | -.10 | -.25 | -.50 | -1 | -2 | -5 | -20 | -75 | 75 | whole |
| Layer | (cm) | Horz | Prep | (- - - - - - - - - - - - - - - - - - - - - - - - - - - % of <2mm Mineral Soil - - - - - - - - - - - - - - - - - - - - - - - - - - - -) | | | | | | | | | | | | (- - - - - - - % of <75mm - - - - - -) | | | | soil |
| | | | | 3A1a1a | | | 3A1a1a | 3A1a1a | 3A1a1a | | 3A1a1a | 3A1a1a | 3A1a1a | 3A1a1a | 3A1a1a | | | | | |
| 01N02927 | 0-1 | C1 | S | 6.5 | 9.3 | 84.2 | 2.2 | | 2.0 | 7.3 | 12.4 | 38.0 | 27.8 | 5.9 | 0.1 | -- | -- | -- | 72 | -- |
| 01N02928 | 1-7 | C2 | S | 7.0 | 7.8 | 85.2 | 2.7 | | 1.8 | 6.0 | 11.7 | 35.9 | 30.0 | 7.5 | 0.1 | -- | -- | -- | 74 | -- |
| 01N02929 | 7-17 | A | S | 10.8 | 11.6 | 77.6 | 3.6 | 1.0 | 3.2 | 8.4 | 14.7 | 34.2 | 22.8 | 5.8 | 0.1 | -- | -- | -- | 63 | -- |
| 01N02930 | 17-27 | Btk1 | S | 12.9 | 10.4 | 76.7 | 4.9 | 2.3 | 3.4 | 7.0 | 11.0 | 30.2 | 26.1 | 9.2 | 0.2 | -- | -- | -- | 66 | -- |
| 01N02931 | 27-44 | Btk2 | S | 13.1 | 10.4 | 76.5 | 5.5 | 2.9 | 4.1 | 6.3 | 9.0 | 30.5 | 28.2 | 8.2 | 0.6 | -- | -- | -- | 68 | -- |
| 01N02932 | 44-65 | Btk3 | S | 17.2 | 11.6 | 71.2 | 7.3 | 4.5 | 4.8 | 6.8 | 8.9 | 26.5 | 27.0 | 8.3 | 0.5 | tr | tr | -- | 62 | tr |
| 01N02933 | 65-87 | Btk4 | S | 24.6 | 11.6 | 63.8 | 8.6 | 13.5 | 6.5 | 5.1 | 7.7 | 28.1 | 21.7 | 5.7 | 0.6 | 8 | 36 | 19 | 84 | 63 |
| 01N02934 | 87-105 | Bkm/Bt | S | 23.5 | 15.7 | 60.8 | 8.1 | 13.7 | 9.0 | 6.7 | 8.5 | 24.0 | 17.7 | 8.2 | 2.4 | 14 | 35 | 10 | 80 | 59 |
| 01N02935 | 105-130 | 2Bkm | S | 14.0 | 17.5 | 68.5 | 4.6 | 9.9 | 10.0 | 7.5 | 10.9 | 27.7 | 21.3 | 6.5 | 2.1 | 7 | 27 | 47 | 92 | 81 |
| 01N02936 | 130-157 | 3Bk1 | S | 11.9 | 18.0 | 70.1 | 3.7 | 8.0 | 9.0 | 9.0 | 11.5 | 25.2 | 22.2 | 7.0 | 4.2 | 2 | 22 | 65 | 95 | 89 |
| 01N02937 | 157-187 | 3Bk2 | S | 9.3 | 22.8 | 67.9 | 3.3 | 5.5 | 10.7 | 12.1 | 20.0 | 27.1 | 12.4 | 3.8 | 4.6 | 5 | 26 | 55 | 93 | 86 |
| 01N02941 | 87-105 | Bkm | S | | | | | | | | | | | | | 15 | 47 | 11 | -- | 73 |
| 01N02942 | 87-105 | Bt | S | | | | | | | | | | | | | -- | -- | -- | -- | -- |

| Bulk Density & Moisture | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- | -12- | -13- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Bulk Density) | | Cole | (- - - - - - - - - - - Water Content - - - - - - - - - - -) | | | | | | WRD | Aggst | | |
| | | | | 33 | Oven | Whole | 6 | 10 | 33 | 1500 | 1500 kPa | Ratio | Whole | Stabl | (- - Ratio/Clay - -) | |
| | Depth | | | kPa | Dry | Soil | kPa | kPa | kPa | kPa | Moist | AD/OD | Soil | 2-0.5mm | CEC7 | 1500 kPa |
| Layer | (cm) | Horz | Prep | (- - - g $cm^{-3}$ - - -) | | | (- - - - - - - - - - - - % of < 2mm - - - - - - - - - - - - -) | | | | | | $cm^3$ $cm^{-3}$ | % | | |
| | | | | DbWR1 | DbWR1 | | DbWR1 | DbWR1 | DbWR1 | 3C2a1a | | 3D1 | | 3F1a1a | | |
| 01N02927 | 0-1 | C1 | S | | | | | | | 3.0 | | 1.010 | | 32 | 1.09 | 0.46 |
| 01N02928 | 1-7 | C2 | S | | | | | | | 3.1 | | 1.010 | | 15 | 0.97 | 0.44 |
| 01N02929 | 7-17 | A | S | 1.50 | 1.55 | 0.011 | 14.1 | 11.6 | 11.5 | 5.1 | | 1.018 | 0.10 | 22 | 0.95 | 0.47 |
| 01N02930 | 17-27 | Btk1 | S | 1.51 | 1.54 | 0.007 | 13.3 | 11.1 | 10.5 | 5.1 | | 1.016 | 0.08 | | 0.71 | 0.40 |
| 01N02931 | 27-44 | Btk2 | S | 1.51 | 1.55 | 0.009 | 15.4 | 14.8 | 12.2 | 5.2 | | 1.017 | 0.11 | | 0.66 | 0.40 |
| 01N02932 | 44-65 | Btk3 | S | 1.53 | 1.59 | 0.013 | 20.0 | 15.7 | 14.9 | 6.6 | | 1.021 | 0.13 | | 0.56 | 0.38 |
| 01N02933 | 65-87 | Btk4 | S | 1.64 | 1.73 | 0.009 | 17.3 | 16.1 | 15.5 | 8.4 | | 1.020 | 0.06 | | 0.34 | 0.34 |
| 01N02933 | 65-87 | Btk4 | S_SK | | | | | | | | | 1.018 | | | | |
| 01N02934 | 87-105 | Bkm/Bt | S | | | | | | | 8.4 | | 1.020 | | | 0.30 | 0.36 |
| 01N02934 | 87-105 | Bkm/Bt | S_SK | | | | | | | | | 1.016 | | | | |
| 01N02935 | 105-130 | 2Bkm | S | 1.56 | 1.60 | 0.002 | 17.4 | 21.4 | 20.2 | 8.9 | | 1.018 | 0.05 | | 0.31 | 0.64 |
| 01N02935 | 105-130 | 2Bkm | S_SK | | | | | | | | | 1.018 | | | | |
| 01N02936 | 130-157 | 3Bk1 | S | | | | | | | 8.7 | | 1.016 | | | 0.31 | 0.73 |
| 01N02936 | 130-157 | 3Bk1 | S_SK | | | | | | | | | 1.012 | | | | |
| 01N02937 | 157-187 | 3Bk2 | S | 1.71 | 1.72 | tr | 18.2 | 16.2 | 15.6 | 9.3 | | 1.029 | 0.02 | | 0.56 | 1.00 |
| 01N02937 | 157-187 | 3Bk2 | S_SK | | | | | | | | | 1.020 | | | | |
| 01N02941 | 87-105 | Bkm | S | | | | | | | 8.7 | | 1.021 | | | | |
| 01N02941 | 87-105 | Bkm | S_SK | | | | | | | | | 1.016 | | | | |
| 01N02942 | 87-105 | Bt | S | | | | | | | 8.4 | | 1.022 | | | | |

pH & Carbonates

| | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (- - - pH | | | | | - - -) | (- - Carbonate - -) As $CaCO_3$ | | (- - Gypsum - - -) As $CaSO_4$*$2H_2O$ | | Resist |
| | | | | | $CaCl_2$ 0.01M | $H_2O$ | Sat | | | <2mm | <20mm | <2mm | <20mm | ohms |
| Layer | Depth (cm) | Horz | Prep | KCl | 1:2 | 1:1 | Paste | Sulf | NaF | (- - - % | | | - - -) | $cm^{-1}$ |
| | | | | | 4C1a2a | 4C1a2a | 4F2 | | 4C1a1a1 | 4E1a1a1a1 | | 4E2a1a1a1 | | |
| 01N02927 | 0-1 | C1 | S | | 7.5 | 7.9 | 7.2 | | 10.0 | 1 | | | | |
| 01N02928 | 1-7 | C2 | S | | 7.6 | 8.1 | | | 10.0 | 1 | | | | |
| 01N02929 | 7-17 | A | S | | 7.7 | 8.1 | | | 10.3 | 2 | | | | |
| 01N02930 | 17-27 | Btk1 | S | | 7.7 | 8.2 | | | 10.5 | 5 | | | | |
| 01N02931 | 27-44 | Btk2 | S | | 7.8 | 8.2 | | | 10.6 | 5 | | | | |
| 01N02932 | 44-65 | Btk3 | S | | 7.8 | 8.2 | | | 10.6 | 5 | | | | |
| 01N02933 | 65-87 | Btk4 | S | | 7.8 | 8.2 | 7.7 | | 10.7 | 21 | 22 | | | |
| 01N02934 | 87-105 | Bkm/Bt | S | | 7.8 | 8.2 | 7.7 | | 10.7 | 33 | 41 | | | |
| 01N02935 | 105-130 | 2Bkm | S | | 8.0 | 8.3 | 7.9 | | 10.8 | 38 | 39 | -- | | |
| 01N02936 | 130-157 | 3Bk1 | S | | 8.0 | 8.2 | 7.8 | | 10.8 | 50 | 62 | -- | | |
| 01N02937 | 157-187 | 3Bk2 | S | | 7.9 | 7.9 | 7.7 | | 10.7 | 46 | 55 | 2 | | |
| 01N02941 | 87-105 | Bkm | S | | 7.9 | 8.2 | | | 10.7 | | | | | |
| 01N02942 | 87-105 | Bt | S | | 7.8 | 8.2 | | | 10.7 | | | | | |

# Stop 3

Pedon ID: 95NM013003 ( Dona Ana, New Mexico ) Print Date: Apr 22 2009 12:25PM
Sampled As : Yucca Coarse-loamy, mixed, thermic Typic Calciargid
USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 95P0455

| PSDA & Rock Fragments | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- | -12- | -13- | -14- | -15- | -16- | -17- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (- - - - - Total - - - - - -) | | | (- - Clay - - -) | | (- - - - Silt - - - - -) | | (- - - - - - - - - - - - Sand - - - - - - - - - - - -) | | | | | ( Rock Fragments (mm) ) | | | | |
| | | | | Clay | Silt | Sand | Fine | $CO_3$ | Fine | Coarse | VF | F | M | C | VC | (- - - - - - - - Weight - - - - - - - -) | | | | >2 mm |
| | | | | < | .002 | .05 | < | < | .002 | .02 | .05 | .10 | .25 | .5 | 1 | 2 | 5 | 20 | .1- | wt % |
| | Depth | | | .002 | -.05 | -2 | .0002 | .002 | -.02 | -.05 | -.10 | -.25 | -.50 | -1 | -2 | -5 | -20 | -75 | 75 | whole |
| Layer | (cm) | Horz | Prep | (- - - - - - - - - - - - - - - - - - - - - - - - - - % of <2mm Mineral Soil - - - - - - - - - - - - - - - - - - - - - - - - - - - - ) | | | | | | | | | | | | (- - - - - - - % of <75mm - - - - - -) | | | | soil |
| | | | | 3A1 | 3A1 | 3A1 | | 3A1 | 3A1 | 3A1 | 3A1 | 3A1 | 3A1 | 3A1 | 3A1 | 3B1 | 3B1 | 3B1 | | |
| 95P03343 | 0-5 | A | S | 10.4 | 11.4 | 78.2 | | | 4.3 | 7.1 | 11.3 | 37.1 | 26.2 | 3.3 | 0.3 | tr | tr | -- | 67 | tr |
| 95P03344 | 5-18 | Btk1 | S | 8.9 | 10.6 | 80.5 | | 2.1 | 5.0 | 5.6 | 10.5 | 38.7 | 28.6 | 2.5 | 0.2 | tr | -- | -- | 70 | -- |
| 95P03345 | 18-31 | Btk2 | S | 12.3 | 11.2 | 76.5 | | 2.6 | 4.3 | 6.9 | 9.4 | 34.8 | 27.4 | 4.2 | 0.7 | 1 | tr | -- | 67 | 1 |
| 95P03346 | 31-48 | Bk21 | S | 21.3 | 15.8 | 62.9 | | 13.2 | 9.4 | 6.4 | 9.6 | 27.3 | 21.0 | 3.7 | 1.3 | tr | 1 | -- | 54 | 1 |
| 95P03347 | 48-65 | Bk22 | S | 18.6 | 14.1 | 67.3 | | 10.5 | 8.2 | 5.9 | 10.9 | 30.9 | 21.3 | 3.4 | 0.8 | 1 | tr | -- | 57 | 1 |
| 95P03348 | 65-85 | Bk31 | S | 15.8 | 13.6 | 70.6 | | 7.5 | 8.2 | 5.4 | 11.4 | 32.6 | 22.3 | 3.3 | 1.0 | 1 | tr | -- | 60 | 1 |
| 95P03349 | 85-114 | Bk32 | S | 13.3 | 13.7 | 73.0 | | 4.8 | 8.4 | 5.3 | 11.4 | 33.5 | 23.8 | 3.6 | 0.7 | 1 | 1 | -- | 62 | 2 |
| 95P03350 | 114-141 | Bk33 | S | 13.3 | 12.3 | 74.4 | | | 6.4 | 5.9 | 10.9 | 33.3 | 25.4 | 3.9 | 0.9 | 1 | tr | -- | 64 | 1 |

Bulk Density & Moisture

| | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- | -12- | -13- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (Bulk Density) | | Cole | (- - - - - - - - - - - Water Content - - - - - - - - - - -) | | | | | | WRD | Aggst | | |
| | | | | 33 | Oven | Whole | 6 | 10 | 33 | 1500 | 1500 kPa | Ratio | Whole | Stabl | (- - Ratio/Clay - -) | |
| | Depth | | | kPa | Dry | Soil | kPa | kPa | kPa | kPa | Moist | AD/OD | Soil | 2-0.5mm | CEC7 | 1500 kPa |
| Layer | (cm) | Horz | Prep | (- - - g $cm^{-3}$ - - -) | | | (- - - - - - - - - - - - % of < 2mm - - - - - - - - - - - - -) | | | | | | $cm^3\ cm^{-3}$ | % | | |
| | | | | | | | | | | 4B2a | | 4B5 | | | 8D1 | 8D1 |
| 95P03343 | 0-5 | A | S | | | | | | | 4.4 | | 1.011 | | | 0.84 | 0.42 |
| 95P03344 | 5-18 | Btk1 | S | | | | | | | 4.2 | | 1.011 | | | 0.81 | 0.47 |
| 95P03345 | 18-31 | Btk2 | S | | | | | | | 5.1 | | 1.012 | | | 0.68 | 0.41 |
| 95P03346 | 31-48 | Bk21 | S | | | | | | | 6.9 | | 1.013 | | | 0.34 | 0.32 |
| 95P03347 | 48-65 | Bk22 | S | | | | | | | 10.8 | | 1.012 | | | 0.35 | 0.58 |
| 95P03348 | 65-85 | Bk31 | S | | | | | | | 5.3 | | 1.012 | | | 0.41 | 0.34 |
| 95P03349 | 85-114 | Bk32 | S | | | | | | | 5.2 | | 1.012 | | | 0.50 | 0.39 |
| 95P03350 | 114-141 | Bk33 | S | | | | | | | 5.8 | | 1.013 | | | 0.56 | 0.44 |

Carbon & Extractions

| | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- | -12- | -13- | -14- | -15- | -16- | -17- | -18- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (- - - - - Total - - - - -) | | | Org | C/N | (- - - Dith-Cit Ext - - -) | | | (- - - - - - Ammonium Oxalate Extraction - - - - - -) | | | | | | (- - - Na Pyro-Phosphate - - -) | | | |
| | Depth | | | C | N | S | C | Ratio | Fe | Al | Mn | Al+½Fe | ODOE | Fe | Al | Si | Mn | C | Fe | Al | Mn |
| Layer | (cm) | Horz | Prep | (- - - - - - % of <2 mm - - - - - -) | | | | | (- - - - - - - - - - - - - - - - - - - - % of < 2mm - - - - - - - - - - - - - - - - - -) | | | | | | | | mg $kg^{-1}$ | (- - - - - - % of < 2mm - - - - - -) | | | |
| | | | | | | | 6A1c | | | | | | | | | | | | | | |
| 95P03343 | 0-5 | A | S | | | | 0.29 | | | | | | | | | | | | | | |
| 95P03344 | 5-18 | Btk1 | S | | | | 0.27 | | | | | | | | | | | | | | |
| 95P03345 | 18-31 | Btk2 | S | | | | 0.28 | | | | | | | | | | | | | | |
| 95P03346 | 31-48 | Bk21 | S | | | | 0.25 | | | | | | | | | | | | | | |
| 95P03347 | 48-65 | Bk22 | S | | | | 0.09 | | | | | | | | | | | | | | |
| 95P03348 | 65-85 | Bk31 | S | | | | 0.04 | | | | | | | | | | | | | | |
| 95P03349 | 85-114 | Bk32 | S | | | | 0.04 | | | | | | | | | | | | | | |
| 95P03350 | 114-141 | Bk33 | S | | | | 0.02 | | | | | | | | | | | | | | |

pH & Carbonates

| Layer | Depth (cm) | Horz | Prep | -1- KCl | -2- CaCl$_2$ 0.01M 1:2 4C1a2a | -3- $H_2O$ 1:1 4C1a2a | -4- Sat Paste 8C1b | -5- Sulf | -6- NaF | -7- Carbonate As $CaCO_3$ <2mm (%) 6E1g | -8- Carbonate As $CaCO_3$ <20mm (%) | -9- Gypsum As $CaSO_4$*2$H_2O$ <2mm (%) 6F1a | -10- Gypsum As $CaSO_4$*2$H_2O$ <20mm (%) | -11- Resist ohms $cm^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 95P03343 | 0-5 | A | S | | 7.9 | 8.5 | | | | 4 | | | | |
| 95P03344 | 5-18 | Btk1 | S | | 7.9 | 8.5 | | | | 5 | | | | |
| 95P03345 | 18-31 | Btk2 | S | | 7.8 | 8.4 | | | | 8 | | | | |
| 95P03346 | 31-48 | Bk21 | S | | 7.8 | 8.3 | | | | 25 | | | | |
| 95P03347 | 48-65 | Bk22 | S | | 7.8 | 8.3 | | | | 22 | | | | |
| 95P03348 | 65-85 | Bk31 | S | | 8.0 | 8.5 | | | | 17 | | | | |
| 95P03349 | 85-114 | Bk32 | S | | 7.9 | 8.7 | 8.2 | | | 12 | | | | |
| 95P03350 | 114-141 | Bk33 | S | | 8.0 | 8.7 | 8.1 | | | 9 | | | | |

# Stop 4

**Berino, taxadjunct**

Fine-loamy, mixed, superactive, thermic Typic Petroargids

| | | |
|---|---|---|
| Particle Size Control Section: | 39 to 89 cm. | |
| Diagnostic Features: | ochric epipedon | 11 to 22 cm. |
| | cambic horizon | 22 to 39 cm. |
| | argillic horizon | 39 to 123 cm. |
| | calcic horizon | 72 to 200 cm. |
| | petrocalcic horizon | 123 to 143 cm. |

Soil Survey Area: NM690 -- Dona Ana County Area, New Mexico. Map Unit: BJ -- Berino-Bucklebar association

Landform: Relict basin floor
Parent Material: Aolian sands over mixed alluvium of the Rio Grande River
Elevation: 4316ft, 1315m

C1--0 to 6 centimeters; yellowish red (5YR 5/6) broken face loamy fine sand, yellowish red (5YR 4/6) broken face, moist; 5 percent clay; strong thick platy structure, and strong very thin platy structure; friable, slightly hard, nonsticky, nonplastic; common fine roots and few very fine roots; many very fine irregular pores; noneffervescent, by HCl, 1 normal; abrupt smooth boundary.

C2--6 to 11 centimeters; yellowish red (5YR 4/6) broken face loamy fine sand, reddish brown (5YR 4/4) broken face, moist; 8 percent clay; strong very thick platy structure, and moderate medium subangular blocky structure; very friable, slightly hard, nonsticky, nonplastic; common fine roots and few very fine roots; few fine tubular and many very fine irregular pores; very slight effervescence, by HCl, 1 normal; abrupt wavy boundary.

Ab--11 to 22 centimeters; reddish brown (5YR 5/4) broken face loamy fine sand, reddish brown (5YR 4/4) broken face, moist; 9 percent clay; weak medium subangular blocky structure; very friable, slightly hard, nonsticky, nonplastic; common medium roots and few very fine roots; many very fine irregular pores; strong effervescence, by HCl, 1 normal; clear wavy boundary.

Bwb1--22 to 39 centimeters; strong brown (7.5YR 4/6) broken face fine sandy loam, reddish brown (5YR 4/4) broken face, moist; 11 percent clay; weak coarse subangular blocky structure; very friable, slightly hard, nonsticky, nonplastic; few medium roots and few very fine roots; many very fine irregular pores; 1 percent subrounded igneous rock fragments; violent effervescence, by HCl, 1 normal; clear wavy boundary.

Bwb2--39 to 53 centimeters; strong brown (7.5YR 4/6) broken face fine sandy loam, reddish brown (5YR 4/4) broken face, moist; 13 percent clay; weak very coarse subangular blocky structure; very friable, slightly hard, slightly sticky, nonplastic; few very fine roots; many very fine irregular pore13(a)34 Tw -29.9822Tdar obou-1(n)5(d)-1(ed)5( )6(fo)6(b

Bkkmb--123 to 143 centimeters; pink (7.5YR 8/3) broken face, pink (7.5YR 7/4) broken face, moist; weak very thick platy structure; weakly cemented; moderate excavation difficulty; 2 percent subrounded igneous rock fragments; violent effervescence, by HCl, 1 normal; clear irregular boundary.

Bkkb--143 to 162 centimeters; pink (5YR 8/3) broken face sandy loam, pink (7.5YR 7/4) broken face, moist; 16 percent clay; moderate coarse subangular blocky structure; firm, hard, nonsticky, nonplastic; few very fine irregular pores; carbonate, finely disseminated throughout and 22 percent medium spherical carbonate nodules throughout and 15 percent coarse irregular carbonate masses throughout; violent effervescence, by HCl, 1 normal; clear irregular boundary.

Bkb--162 to 200 centimeters; 90 percent pink (5YR 8/3) broken face and 10 percent yellowish red (5YR 5/6) broken face sandy clay loam, 90 percent light reddish brown (5YR 6/4) broken face and 10 percent reddish brown (5YR 4/4) broken face, moist; 22 percent clay; moderate medium prismatic structure, and moderate coarse subangular blocky structure; firm, hard, slightly sticky, slightly plastic; carbonate, finely disseminated throughout and 5 percent fine spherical carbonate nodules throughout and 15 percent fine threadlike carbonate masses throughout and 8 percent coarse irregular carbonate masses throughout; violent effervescence, by HCl, 1 normal.

*** Primary Characterization Data ***

Pedon ID: S09NM013001 ( Dona Ana County, New Mexico ) Print Date: Apr 17 2009 12:37PM

Sampled As : Berino Fine-loamy, mixed, superactive, thermic Typic Petroargid

USDA-NRCS-NSSC-National Soil Survey Laboratory ; Pedon No. 09N0343

PSDA & Rock Fragments

| Layer | Depth (cm) | Horz | Prep | -1- Total Clay < .002 | -2- Total Silt .002 -.05 | -3- Total Sand .05 -2 | -4- Clay Fine < .0002 | -5- Clay $CO_3$ < .002 | -6- Silt Fine .002 -.02 | -7- Silt Coarse .02 -.05 | -8- Sand VF .05 -.10 | -9- Sand F .10 -.25 | -10- Sand M .25 -.50 | -11- Sand C .5 -1 | -12- Sand VC 1 -2 | -13- Rock Fragments Weight 2 -5 | -14- Rock Fragments Weight 5 -20 | -15- Rock Fragments Weight 20 -75 | -16- .1- 75 % of <75mm | -17- >2 mm wt % whole soil |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (- - - % of <2mm Mineral Soil - - -) | | | | | | | | | | | | | | | | |
| | | | | 3A1a1a | | | 3A1a1a | 3A1a1a | 3A1a1a | | 3A1a1a | 3A1a1a | 3A1a1a | 3A1a1a | 3A1a1a | | | | | |
| 09N02008 | 0-6 | C1 | S | 6.9 | 3.6 | 89.5 | 3.9 | | 0.7 | 2.9 | 12.3 | 45.3 | 30.5 | 1.2 | 0.2 | -- | -- | -- | 77 | -- |
| 09N02009 | 6-11 | C2 | S | 8.8 | 5.5 | 85.7 | 4.1 | | 1.1 | 4.4 | 16.3 | 44.5 | 23.5 | 1.3 | 0.1 | -- | -- | -- | 69 | -- |
| 09N02010 | 11-22 | Ab | S | 9.6 | 5.6 | 84.8 | 4.6 | -- | 1.8 | 3.8 | 11.3 | 42.2 | 29.2 | 2.0 | 0.1 | -- | -- | -- | 74 | -- |
| 09N02011 | 22-39 | Bwb1 | S | 10.4 | 5.2 | 84.4 | 5.1 | 1.3 | 1.8 | 3.4 | 13.0 | 43.4 | 26.8 | 1.1 | 0.1 | -- | -- | -- | 71 | -- |
| 09N02012 | 39-53 | Bwb2 | S | 12.0 | 5.8 | 82.2 | 6.1 | 2.1 | 2.1 | 3.7 | 9.9 | 38.5 | 30.5 | 3.0 | 0.3 | -- | tr | -- | 72 | tr |
| 09N02013 | 53-72 | Btkb1 | S | 16.0 | 6.6 | 77.4 | 7.6 | 3.2 | 3.1 | 3.5 | 11.5 | 34.6 | 26.7 | 4.1 | 0.5 | tr | -- | -- | 66 | tr |
| 09N02014 | 72-86 | Btkb2 | S | 26.0 | 9.0 | 65.0 | 11.1 | 10.6 | 5.6 | 3.4 | 7.6 | 33.6 | 19.6 | 3.6 | 0.6 | tr | -- | -- | 57 | tr |
| 09N02015 | 86-123 | Btkb3 | S | 23.8 | 9.8 | 66.4 | 9.1 | 10.8 | 6.9 | 2.9 | 9.6 | 27.5 | 26.5 | 2.4 | 0.4 | tr | -- | -- | 57 | tr |
| 09N02016 | 123-143 | Bkkmb | S | 17.4 | 20.8 | 61.8 | 5.2 | 10.7 | 14.7 | 6.1 | 12.1 | 27.3 | 18.1 | 3.5 | 0.8 | 1 | tr | -- | 50 | 1 |
| 09N02017 | 143-162 | Bkkb | S | 15.3 | 17.4 | 67.3 | 4.2 | 8.5 | 12.9 | 4.5 | 11.8 | 31.0 | 21.3 | 3.0 | 0.2 | tr | -- | -- | 56 | tr |
| 09N02018 | 162-200 | Bkb | S | 16.2 | 18.8 | 65.0 | 5.4 | 6.2 | 13.8 | 5.0 | 10.4 | 30.8 | 20.2 | 3.3 | 0.3 | tr | tr | -- | 55 | 1 |

Bulk Density & Moisture

| Layer | Depth (cm) | Horz | Prep | -1- Bulk Density 33 kPa | -2- Bulk Density Oven Dry | -3- Cole Whole Soil | -4- Water Content 6 kPa | -5- Water Content 10 kPa | -6- Water Content 33 kPa | -7- Water Content 1500 kPa | -8- Water Content 1500 kPa Moist | -9- Ratio AD/OD | -10- WRD Whole Soil | -11- Aggst Stabl 2-0.5mm | -12- Ratio/Clay CEC7 | -13- Ratio/Clay 1500 kPa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (- - - g $cm^{-3}$ - - -) | | | (- - - pct of < 2mm - - -) | | | | | | $cm^3$ $cm^{-3}$ | % | | |
| | | | | DbWR1 | DbWR1 | | | | DbWR1 | 3C2a1a | | 3D1 | | 3F1a1a | | |
| 09N02008 | 0-6 | C1 | S | | | | | | | 2.8 | | 1.006 | | 6 | 0.77 | 0.41 |
| 09N02009 | 6-11 | C2 | S | | | | | | | 3.3 | | 1.007 | | 6 | 0.80 | 0.38 |
| 09N02010 | 11-22 | Ab | S | 1.54 | 1.58 | 0.009 | | | 6.9 | 4.2 | | 1.009 | 0.04 | 12 | 0.82 | 0.44 |
| 09N02011 | 22-39 | Bwb1 | S | 1.52 | 1.57 | 0.011 | | | 7.8 | 4.4 | | 1.009 | 0.05 | 11 | 0.64 | 0.42 |
| 09N02012 | 39-53 | Bwb2 | S | 1.47 | 1.55 | 0.018 | | | 8.7 | 5.0 | | 1.010 | 0.05 | 10 | 0.62 | 0.42 |
| 09N02013 | 53-72 | Btkb1 | S | 1.41 | 1.48 | 0.016 | | | 10.4 | 6.1 | | 1.012 | 0.06 | 14 | 0.56 | 0.38 |
| 09N02014 | 72-86 | Btkb2 | S | 1.43 | 1.51 | 0.018 | | | 13.0 | 8.9 | | 1.016 | 0.06 | 8 | 0.41 | 0.34 |
| 09N02015 | 86-123 | Btkb3 | S | 1.58 | 1.66 | 0.017 | | | 12.1 | 8.1 | | 1.014 | 0.06 | 9 | 0.35 | 0.34 |
| 09N02016 | 123-143 | Bkkmb | S | 1.57 | 1.65 | 0.017 | | | 13.7 | 9.1 | | 1.012 | 0.07 | 93 | 0.33 | 0.52 |
| 09N02017 | 143-162 | Bkkb | S | 1.43 | 1.51 | 0.018 | | | 16.2 | 8.3 | | 1.012 | 0.11 | 90 | 0.39 | 0.54 |
| 09N02018 | 162-200 | Bkb | S | 1.37 | 1.44 | 0.017 | | | 19.3 | 9.0 | | 1.014 | 0.14 | 81 | 0.47 | 0.56 |

# *** Primary Characterization Data ***

Pedon ID: S09NM013001 ( Dona Ana County, New Mexico ) Print Date: Apr 17 2009 12:37PM

Sampled As : Berino Fine-loamy, mixed, superactive, thermic Typic Petroargid

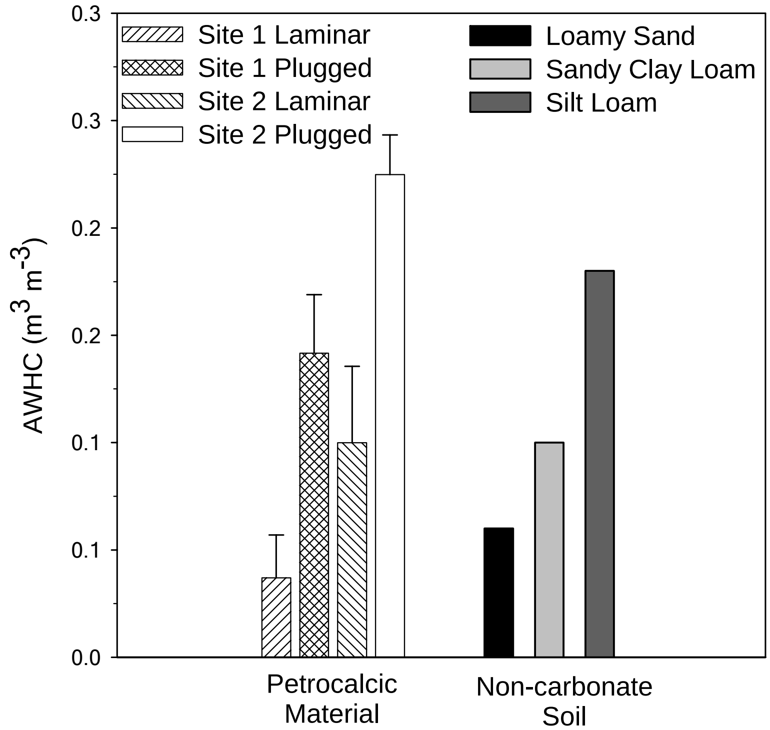
USDA-NRCS-NSSC-National Soil Survey Laboratory ; Pedon No. 09N0343

## Carbon & Extractions

| | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- | -12- | -13- | -14- | -15- | -16- | -17- | -18- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (- - - - - Total - - - - -) | | | Org | C/N | (- - - Dith-Cit Ext - - -) | | | (- - - - - - Ammonium Oxalate Extraction - - - - - -) | | | | | | (- - - Na Pyro-Phosphate - - -) | | | |
| | Depth | | | C | N | S | C | Ratio | Fe | Al | Mn | Al+½Fe | ODOE | Fe | Al | Si | Mn | C | Fe | Al | Mn |
| Layer | (cm) | Horz | Prep | (- - - - - - % of <2 mm - - - - - -) | | | | | (- - - - - - - - - - - - - - - - - - - - % of < 2mm - - - - - - - - - - - - - - - - - -) | | | | | | | | mg $kg^{-1}$ | (- - - - - - % of < 2mm - - - - -) | | | |
| | | | | 4H2a | 4H2a | 4H2a | | | 4G1 | 4G1 | 4G1 | | 4G2a | 4G2a | 4G2a | 4G2a | 4G2a | | | | |
| 09N02008 | 0-6 | C1 | S | 0.20 | 0.026 | 0.02 | | 5 | 0.3 | -- | -- | 0.04 | tr | 0.02 | 0.03 | 0.02 | 34.5 | | | | |
| 09N02009 | 6-11 | C2 | S | 0.21 | 0.001 | 0.01 | | 121 | 0.5 | -- | -- | 0.05 | 0.01 | 0.02 | 0.04 | 0.02 | 44.8 | | | | |
| 09N02010 | 11-22 | Ab | S | 0.37 | 0.044 | 0.01 | | 4 | 0.4 | -- | -- | 0.05 | 0.01 | 0.02 | 0.04 | 0.02 | 40.3 | | | | |
| 09N02011 | 22-39 | Bwb1 | S | 0.47 | 0.018 | 0.01 | | 8 | 0.4 | tr | -- | 0.05 | 0.01 | 0.02 | 0.04 | 0.02 | 35.4 | | | | |
| 09N02012 | 39-53 | Bwb2 | S | 0.61 | 0.047 | -- | | 5 | 0.5 | -- | -- | 0.06 | 0.01 | 0.02 | 0.05 | 0.02 | 32.6 | | | | |
| 09N02013 | 53-72 | Btkb1 | S | 0.91 | 0.047 | tr | | 5 | 0.4 | tr | -- | 0.06 | 0.01 | 0.02 | 0.05 | 0.03 | 32.2 | | | | |
| 09N02014 | 72-86 | Btkb2 | S | 2.06 | 0.035 | 0.01 | | 6 | 0.4 | -- | -- | 0.05 | 0.01 | 0.02 | 0.05 | 0.03 | 20.4 | | | | |
| 09N02015 | 86-123 | Btkb3 | S | 2.37 | 0.010 | tr | | 12 | 0.3 | -- | -- | 0.04 | tr | 0.01 | 0.03 | 0.02 | 15.5 | | | | |
| 09N02016 | 123-143 | Bkkmb | S | 4.13 | 0.020 | 0.01 | | 5 | 0.2 | -- | -- | 0.04 | 0.01 | 0.01 | 0.03 | 0.02 | 16.6 | | | | |
| 09N02017 | 143-162 | Bkkb | S | 3.52 | -- | 0.02 | | | 0.2 | -- | -- | 0.02 | tr | 0.01 | 0.01 | 0.01 | 7.3 | | | | |
| 09N02018 | 162-200 | Bkb | S | 2.84 | 0.030 | 0.02 | | 3 | 0.2 | -- | -- | 0.02 | tr | 0.01 | 0.02 | 0.02 | 9.3 | | | | |

## pH & Carbonates

| | | | | -1- | -2- | -3- | -4- | -5- | -6- | -7- | -8- | -9- | -10- | -11- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (- - - - - - - - - - - - - - - - - - pH - - - - - - - - - - - - - - - - -) | | | | | | (- - Carbonate - -) | | (- - Gypsum - - -) | | |
| | | | | | $CaCl_2$ | | | | | As $CaCO_3$ | | As $CaSO_4$*$2H_2O$ | | Resist |
| | Depth | | | | 0.01M | $H_2O$ | Sat | | | <2mm | <20mm | <2mm | <20mm | ohms |
| Layer | (cm) | Horz | Prep | KCl | 1:2 | 1:1 | Paste | Oxid | NaF | (- - - - - - - - - - - - - % - - - - - - - - - - - -) | | | | $cm^{-1}$ |
| | | | | | 4C1a2a | 4C1a2a | 4F2 | | | 4E1a1a1a1 | | 4E2a1a1a1 | | |
| 09N02008 | 0-6 | C1 | S | | 7.7 | 8.3 | | | | 1 | | | | |
| 09N02009 | 6-11 | C2 | S | | 7.8 | 8.5 | | | | 1 | | | | |
| 09N02010 | 11-22 | Ab | S | | 7.8 | 8.5 | | | | 2 | | | | |
| 09N02011 | 22-39 | Bwb1 | S | | 7.8 | 8.5 | | | | 3 | | | | |
| 09N02012 | 39-53 | Bwb2 | S | | 7.8 | 8.4 | | | | 3 | | | | |
| 09N02013 | 53-72 | Btkb1 | S | | 7.9 | 8.4 | | | | 6 | | | | |
| 09N02014 | 72-86 | Btkb2 | S | | 7.8 | 8.5 | | | | 15 | | | | |
| 09N02015 | 86-123 | Btkb3 | S | | 8.0 | 8.7 | 8.1 | | | 19 | | | | |
| 09N02016 | 123-143 | Bkkmb | S | | 8.1 | 8.5 | 8.3 | | | 34 | | -- | | |
| 09N02017 | 143-162 | Bkkb | S | | 8.3 | 8.6 | 8.4 | | | 28 | | -- | | |
| 09N02018 | 162-200 | Bkb | S | | 8.4 | 8.6 | 8.4 | | | 23 | | -- | | |




Available water holding capacity (AWHC) of two morphologies of petrocalcic horizon compared to non-carbonate AWHC of three soil textures. Error bars represent sample standard deviations (adapted from Duniway et al. 2007).

Duniway MC, Herrick JE, Monger HC. 2007. The high water-holding capacity of petrocalcic horizons. *Soil Science Society of America Journal* **71** : 812-819.

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# Workshop 3
# Dynamic Soil Properties Demonstration

## How this Workshop Will Be Run

- After the **Introduction**, split into 3 groups and go to **Station 1, 2, or 3**.
- At the end of 30 minutes, move to the next station.
- Everyone goes to each station once.
- If time is available at the end, revisit any station.

**Station 1. Plot Design and Pedoderm Features**
**Station 2. Soil Profile and Soil Samples**
**Station 3. Vegetation Sampling**

**Workshop Summary**
The purposes of this workshop are to 1) discuss the soil survey vision for documenting dynamic soil properties and soil change and 2) demonstrate field methods used in a comparison study. The **Soil Change Guide: Procedures for Soil Survey and Resource Inventory** provides a detailed description of how to conduct a comparison study for a phase of a soil map unit component. The outcome is an inventory of management-dependent soil properties at multiple scales. The procedures apply to all land uses. We will demonstrate data collection procedures on rangeland and provide examples of summary data that can be developed from a project. The new soil survey data will be used to meet customer needs, including:

- Products for agency programs and planners to help recommend and evaluate practices.
- Products to educate the public about how soils change in response to human activity.
- Information to assist in quantifying the benefits of conservation systems.
- Interpretations for use by decision makers to help identify and protect lands at risk of irreversible change (e.g. erosion, salinization, contamination, sulfurization).
- Soil survey data and interpretations to support sustainable land management, including maintenance or improvement of soil quality, soil function, and ecosystem services.

## Introduction and Sampling at Multiple Scales — 30 min

Karl Hipple, Nat. Ldr, Soil Interpretations
Larry West, Nat. Ldr, Soil Research and Laboratory
Arlene Tugel, Soil Scientist, NRCS

### What is the Current Situation?

Many soil properties have changed and can change as a result of management or natural factors such as drought, interacting with land use. Furthermore, changes in dynamic soil properties can affect the land manager's ability to meet productivity, economic and environmental goals. With information about management effects on the soil, managers can select and apply sustainable practices. With a better understanding of how soils change, policy makers can develop programs to limit undesired change. Soil survey customers need information about dynamic soil properties and ecosystem change for many purposes. These include:

- Plan for long-term productivity and sustainability,
- Protect and restore ecosystem functions and services provided by soil,
- Design monitoring plans and interpret assessments for resource condition,
- Predict land use and management effects on soil, and
- Adjust management practices for changes in near-surface conditions.

Currently, national soil survey databases include soil property information for relatively static soil properties, such as texture. The databases also include properties affected by management, such as soil organic matter. The databases do not, however, distinguish the values of soil properties according to their land use, management system, ecological state, or plant community. In other words, they do not include the dynamic soil property information that is needed by customers. Capturing information about changes in soil and communicating it to a wide variety of audiences will require new procedures and new technologies for soil survey.

> Dynamic soil properties are soil properties that change within the human time scale (centuries, decades or less). Examples include soil organic matter, bulk density, pH, EC, and infiltration rate.

### What is the Vision?

In NRCS, soil change is a part of the new soil survey. The soil change vision and mission statements are as follows:

**Enhancing the National Cooperative Soil Survey data and products with information about soil change and its consequences.**

**The soil survey of the future will inventory and predict soil change over the human time scale, determine the mechanisms, and interpret the consequences of those changes.**

The Soil Survey Division has a strategic plan to incorporate management-based information in soil survey databases. The emphasis is on soil change within the human time scale. In addition to improving the accuracy of existing information, new soil survey data will be used to:

- Build a point data set of management-dependent properties (build DATABASES).

- Determine what is attainable (set PLANNING goals).
- Interpret soil function (predict consequences of soil change for PLANNING).
- Establish benchmark soil values (support MODELS that extend or simulate data).

**How will We Get It Done?**

There is a basic long-term strategy for achieving the objectives. Data will be collected on replicated plots on the same kind of soil, stored in a point database and summarized for specific management systems. The summarized data will be used to build a dynamic soil properties data set and interpretations for benchmark soils. Using simulation models and other extrapolation methods, information in the point data set will be applied to other similar soils and then used to populate the soil map unit database (aggregated database) for Web Soil Survey and the Soil Data Mart. NCSS participation is needed in research, development and testing for methods and new interpretations.

**What Procedures will We Use?**

Procedures are now available. The ***Soil Change Guide: Procedures for Soil Survey and Resource Inventory, Version 1.1*** (**Guide**) is designed primarily for soil survey update projects on benchmark soils. It can also be used for ecological site inventory work.

http://soils.usda.gov/technical/soil_change/index.html

The **Guide** describes how to conduct a comparison study for a phase of a soil map unit component. Instructions are provided for project planning, data collection, data analysis, and storage. The **Guide** is not intended to be used as a monitoring guide, although some of the field methods are useful for monitoring. Projects conducted according to the **Guide** will provide important information about soil quality and soil function.

*The **Guide** was developed by the Natural Resources Conservation Service, the Jornada Experimental Range of the Agricultural Research Service, and the National Park Service in cooperation with the Forest Service and Bureau of Land Management. Procedures were field tested by soil survey, field, and state offices and cooperators during several pilot projects.*

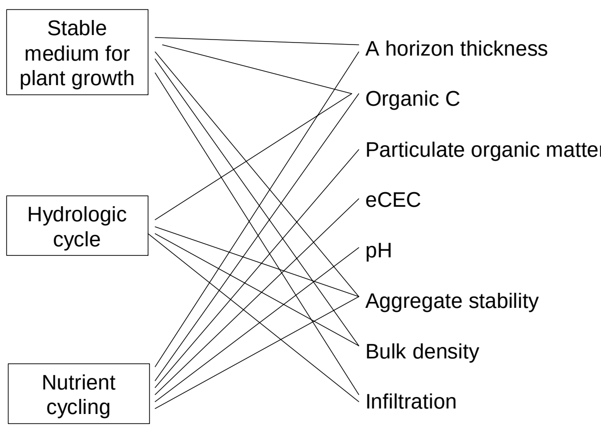
**What is the Minimum Data Set?**

Building the dynamic soil properties point data set for the nation requires a consistent, standardized approach. In order to ensure comparability of data, a core set of soil and vegetation properties, called the minimum data set, will be included in each project. The minimum data set of dynamic soil properties were selected by a group of over 40 people using five criteria (Table 1). Each project also includes properties that are important for interpreting dynamic soil properties and may be relatively stable (e.g., soil horizon thickness, particle size distribution, properties used in lieu of texture, rock fragments, CEC, and mineralogy).

**Table 1. Minimum Data Set and Criteria.**

| Dynamic soil properties | Criteria |
|---|---|
| Organic C<br>pH<br>EC<br>Bulk density/soil porosity<br>Soil Structure<br>Aggregate stability (wet)<br>Total N<br>Soil Stability Test Kit | • The properties should be sensitive to disturbances or management. The properties could recover within a few hundred years in the absence of anthropogenic disturbance or under proper management, or the change may be nearly irreversible.<br>• The relationships between the properties and the processes or functions they reflect should be clearly defined (Figure 1).<br>• They should be relatively insensitive to daily or seasonal fluctuations in environmental conditions of moisture, temperature, and light, or such fluctuations are well-understood and can be quantitatively predicted.<br>• They should be easy to measure accurately and precisely by different people and by the same person at different times.<br>• The cost and time, both in the field and the laboratory, to obtain the required number of measurements is low. |

**Figure 1. Functions and their Relationship to Important Dynamic Soil Properties.**




## What are Supplemental and Experimental Properties?

Properties in addition to the minimum data set can be included in a project. Some supplemental properties are functionally important for some but not all soils (e.g., SAR, forest floor carbon). Other supplemental properties do not meet all the criteria for the minimum data set, often for reasons of cost or reproducibility of the measurement. Infiltration is an example. Experimental properties are generally difficult to interpret or they are from a method is not standardized. A number of biological properties are considered experimental. Additional research is needed to simplify methods and help interpret many of these properties.

**Table 2. Supplemental and Experimental Soil Properties.**

| Soil Property | | | |
|---|---|---|---|
| **Soil horizon: chemical, carbon and biological measures** | **Soil horizon: hydrology** | **Other field measures** | **Forest floor** |
| eCEC, mineral CEC | Saturated hydraulic conductivity (by horizon) Amoozemeter | Dry aggregate stability | Forest floor (O horizon), mass |
| KCl-Al | Ponded infiltration, single ring | Pocket penetrometer | Forest floor (O horizon), total C |
| $CaCO_3$ | Water retention | Impact penetrometer | Forest floor (O horizon), total N |
| SAR | Pore size distribution | Modified singleton blade | Forest floor (O horizon), OM (loss on ignition) |
| C:N ratio (Organic C:Total N) | Other | Torvane | Downed wood, total mass |
| Plant available P | | Albedo, bare soil | Downed wood, total C |
| Total ions (Ion resin capsules) | | Soil temperature | Downed wood, total N |
| Potentially mineralizable N | | Other | Downed wood, OM (loss on ignition) |
| POM (Total, POM-C and POM-N) | | | Other |
| Active C | | | |
| Active C kit (field) | | | |
| Microbial biomass-C | | | |
| B-glucosidase | | | |
| Other | | | |

Vegetation properties will be measured where a plant community is present. Minimum data sets for use on rangelands and forest lands are provided in the **Guide**. Supplemental or experimental properties can be added.

**What is a Comparison Study?**
A comparison study is a project in which two or more different management conditions on the same kind of soil are compared. Primary features of a comparison study are listed below.

- Documents spatial variability at two scales.
- Integrates soil and vegetation data collection. Methods are tailored to each land use.
- Uses a minimum data set of functionally important soil and vegetation properties.
- Uses the space-for-time substitution technique. We infer that differences between a reference state and some other management system represent changes in soil properties over time.

**What Scales Are Included?**
The sample design for a project includes two spatial scales in the standard method.

- Capture regional-scale variability across the MLRA or other region (entire extent of the soil map unit).
- Capture fine-scale variability on plots.

Multiple plots for each management system are selected from the entire MLRA (minimum of 5). Soil sample locations are randomly or systematically placed on each plot (minimum of 5). Data are summarized by plot, and plot means are summarized for each management system sampled. Then the means for management systems are compared.

**What are the Soil, Ecological Site and Ecological State at this Plot?**

The soil is Berino, taxadjunct, a fine-loamy, mixed, superactive, thermic Typic Petroargid.

Berino, tax. is correlated to the Sandy Ecological Site in MLRA 42D (MLRA 42, Southern Desertic Basins, Plains and Mountains).

The ecological state is a shrub-encroached bunchgrass grassland.

Data collected from this plot will be compared to data for the “reference state,” a black grama grassland (see Ecological Site Workshop). Additional information about the ecological site, the state and transition model, and a representative soil profile will be provided during tour stops in the Ecological Site Workshop.

| **Reference State** | **This Plot** |
|---|---|
| **Black Grama Grassland**<br>Summary of 3 plot means | **Shrub-encroached Bunchgrass Grassland**<br>Summary of 1 plot |
| | |

## Station 1. Plot Design and Pedoderm Features — 30 min

**Arlene Tugel, Soil Scientist, NRCS**
**Dave Lightle, Agronomist, NRCS**

Instructions for plot layout and methods to collect information for the pedoderm (the air-soil interface) are described in the **Soil Change Guide**.

1. Plot configuration

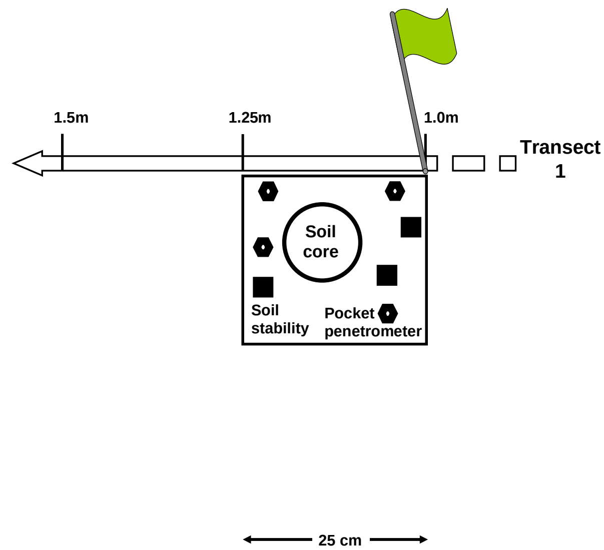
The plot is the primary sampling unit for a project (Figure 2). The plot should be large enough to capture variability in the plant community but not so large that it encompasses more than one kind of soil. The standard method for grasslands, shrublands and savanna ecosystems uses a 20m by 20m plot. Smaller plots can be 2 T3y but the

2. Soil Sample Location
A 25cm x 25cm plot is placed adjacent to the transect tape and the flag (Figure 3). Soil samples are collected on one side of the tape and vegetation data on the other to avoid trampling problems.

Measurements at each soil sample location include:

- Bulk density and soil samples (demonstrated at Station 2).
- Soil stability
- Penetration resistance
- Cover and
- Pedoderm classes.

Figure 3.




3. Cover and pedoderm classes
Cover over the 25cm x 25cm area is described by assigning a code for the dominant type of vegetation in the canopy (NC = no canopy, PG = perennial grass, AG = annual grass, F = forb, Sh = shrub, T = tree). The cover code can be used to group and analyze soils data for similar cover types. Soil surface features such as physical, chemical or biological crusts, rock pavement, and duff are described by assigning the dominant pedoderm class observed at the soil sample location. Pedoderm classes are used to describe the air-soil interface and reflect resistance to erosion as well as conditions affecting infiltration.

4. Penetration resistance
A pocket penetrometer is used to measure the penetration resistance of the soil surface. This measure is useful for characterizing physical crusts.

5. Soil stability
The soil stability test is conducted to provide information about soil structural development, resistance to erosion, and biological activity. It is part of the minimum data set. Three samples each are collected of the surface 2-3mm and the sub-surface (2-2.5cm) and analyzed using the field soil stability kit (Herrick et al., 2005). A stability class of 1 thru 6 is assigned to each sample. Class 6 has the greatest stability and resistance to erosion. Soils with low subsurface values have low resistance to erosion after a physical disturbance.

6. Data summary--Pedoderm

- Soil pedoderm class at the 25cm x 25cm soil sample location: WP, weak physical or biological crust, which can be disrupted by raindrop impact.
- Soil surface stability of the shrub-encroached bunchgrass grassland ecological state is lower than the reference state (black grama grassland). Soil sub-surface stability is very similar. Low stability values indicate low resistance to erosion.
- Control charts (Figure 4) of soil stability allow easy comparison of the bunchgrass state (dashed red line) to the reference state.

**Figure 4. Control Charts for Two Ecological States: Surface and Subsurface Soil Stability.**

Legend

Each box plot shows high and low plot means as well as mean and median of 3 plots for the black grama grassland state. Solid line = median. Dashed line = mean.
Long horizontal lines indicate high and low plot means of the reference state.
Dashed red line represents 1 plot mean for the shrub-encroached bunchgrass state.

## Station 2. Soil Profile and Soil Samples — 30 min

**Cindy Stiles, Research Soil Scientist, NRCS**
**Susan Andrews, Soil Ecologist, NRCS**

Standard Methods and the Minimum Data Set

The standard methods for soil horizons are (1s aktd tiss station )Tj0 Tc -0.0006 Tw 12 0 Td The standard methods include: detaild plo. (Th pro, **Soil Change Guide** )]TJ0.0006 Tc -0.0006 Tw210.305 0 Td[ of hed m,b-1(ali

This method uses the pocket penetrometer to collect a set of measures on the profile face. These measures ostensibly detect layers that inhibit root penetration and water infiltration and are in support of observed trends made in the soil description. A ruler marked with ten depth intervals (3 cm increments) is hung on the pit face and four measures are made at each depth across the horizon. Because of the wide range of conditions experienced in the pit, moisture status, the type of penetrometer tip and the calibrated spring class used for the measure must be recorded for each measurement. This is an experimental method.

3. Bulk Density

Bulk density sampling for DSP is done primarily using the core method, sampling the whole horizon. Horizon thickness is indicated by a rubber band placed around the core. Horizons that are deeper than the length of the core must be divided into two depths and each sampled to complete the entire process. The depth to the top of the soil (ring height) is measured at four locations around the outer circumference of the ring prior to removing the sample from the soil. Once removed from the horizon, samples are transferred to tightly sealed bags and field moisture content is determined off-site. Bags must be clearly labeled with appropriate redundant labeling as described in the **Soil Change Guide**. Samples are collected for each horizon, with additional samples taken for the biologically active upper portion of the A horizon (e.g., 0-2, 2-5, 5-10 cm). The base of the last soil core should be equivalent to the standard depth of 40 cm. If there is a surface O horizon, the base of the last core should be 40 cm below the mineral soil boundary.

4. Soil Samples

Bulk soil samples are necessary for analytical procedures that may be performed in the local soil survey office or other lab (e.g., Soil Survey Laboratory). Samples are taken from each horizon, collecting materials within the whole depth of each horizon and coinciding with bulk density core collection. Soil materials scraped away from the core can be scooped to the large soil pan, where it is then mixed and transferred to a labeled bag. Labeling follows the DSP convention as described in the **Soil Change Guide**. Recommended minimum sample size is about three quarts (1500 g).

5. Data summary—Soil horizons

Soil samples were collected for prescribed depths (0-1, 1-5, 5-18, 18-50cm) on black grama plots. Data for the reference state (black grama grassland) is a mean of 3 plot means. For the shrub-encroached bunchgrass community, only one plot was sampled; samples were collected and analyzed by horizon and then converted to prescribed depths.

In a non-statistical comparison, we observe the following: the bunchgrass state organic carbon is lower and bulk density and sand content are higher than for the reference state.

**Table 3. Plot Average of Selected Soil Properties for the Shrub-encroached Bunchgrass Ecological State.** Summary of 5 soil sample locations.

| | **Average thickness (cm)** | **Bulk density ((g/cm$^3$)** | **Estimated organic carbon* (%)** | **$CaCO_3$ Equivalent (%)** | **Soil Particle Size (%)** Pipette | **Aggregate stability (%)** |
|---|---|---|---|---|---|---|

## Table 4. Summary Soil Data for Two Ecological States.

| | | Reference state Black grama† | | DSP Demo Plot Shrub-encroached bunchgrass‡ |
|---|---|---|---|---|
| **Variable** | **Depth** | **Mean** | **Std. dev** | **Mean** |
| **Soil Stability** | Surface | 4.6 | 0.93 | 1.4 |
| | Sub-surface | 1.6 | 0.44 | 1.9 |
| **Bulk Density (g * cm-3)** | 0-1 | n/a | n/a | 1.57 |
| | 1-5 | 1.49 | 0.02 | 1.53 |
| | 5-18 | 1.55 | 0.03 | 1.56 |
| | 18-50 | 1.41 | 0.04 | 1.53 |
| **% Carbon (organic)** | 0-1 | 0.44 | 0.02 | 0.29 |
| | 1-5 | 0.30 | 0.02 | 0.27 |
| | 5-18 | 0.34 | 0.05 | 0.20 |
| | 18-50 | 0.32 | 0.04 | 0.18 |
| **Soil Carbon (organic) (Mg C * ha-1)** | 1-5 | 1.8 | 0.1 | 1.7 |
| | 5-18 | 6.9 | 0.9 | 4.1 |
| | 18-50 | 14.4 | 0.9 | 8.8 |
| **Soil Carbon (organic) (t C * acre-1)** | 1-5 | 1.0 | 0.1 | 0.9 |
| | 5-18 | 3.8 | 0.4 | 2.3 |
| | 18-50 | 8.0 | 0.4 | 4.9 |
| **%Clay** | 0-1 | 5.7 | 0.5 | 8.2 |
| | 1-5 | 6.3 | 0.6 | 8.4 |
| | 5-18 | 8.4 | 1.2 | 9.6 |
| | 18-50 | 11.8 | 2.4 | 11.2 |
| **%Silt** | 0-1 | 10.4 | 0.9 | 5.8 |
| | 1-5 | 10.0 | 0.5 | 6.0 |
| | 5-18 | 10.5 | 1.1 | 5.5 |
| | 18-50 | 10.4 | 0.9 | 4.7 |
| **%Sand** | 0-1 | 83.9 | 1.3 | 86.0 |
| | 1-5 | 83.7 | 1.0 | 85.5 |
| | 5-18 | 81.1 | 2.2 | 84.9 |
| | 18-50 | 77.8 | 3.2 | 84.1 |

† clay, silt, sand by hydrometer. ‡ clay, silt, sand by pipette.

## Figure 5. Box Plots for Two Ecological States: Selected Properties.

Legend

Each box plot shows high and low plot means as well as mean and median of 3 plots for the black grama grassland state. Soil line = median. Dashed line = mean.
Dashed red line represents 1 plot mean for the shrub-encroached bunchgrass state.

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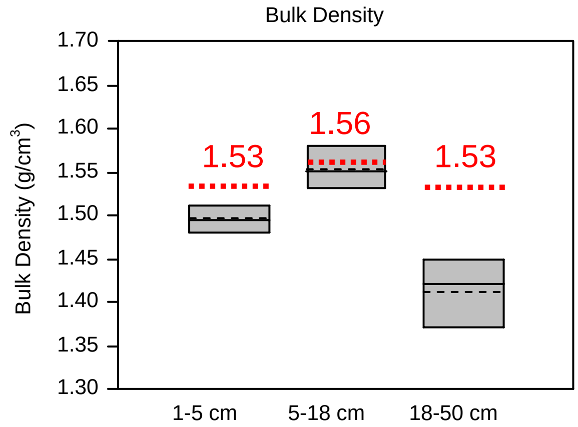


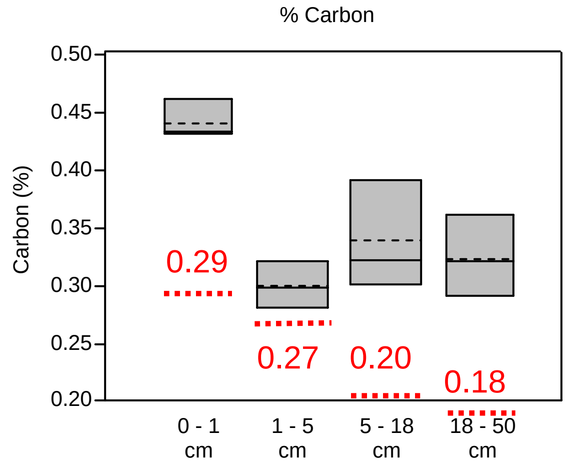


| **Station 3. Vegetation Sampling**<br>**Curtis Talbot, Range Management Specialist, NRCS**<br>**Laura Burkett, Range Technician, ARS** | **30 min** |
|---|---|

Standard Methods and the Minimum Data Set

The standard methods for vegetation are shown at this station. The minimum vegetation data set for grassland, shrubland, and savanna ecosystems, as described in the **Soil Change Guide**, includes total canopy (foliar) cover, canopy cover by functional group, bare ground, litter cover, biological crust cover, rock fragment cover, canopy gaps, basal gaps, and annual herbaceous production. Annual woody production is collected for plant communities with woody species. Three field methods are used to collect these data. Data can be recorded on a paper form or a tablet PC.

1. Line-point Intercept

This method is used to collect data for total canopy (foliar) cover, canopy cover by functional group, bare ground, litter cover biological crust cover, and rock fragment cover. It is relatively rapid to conduct and requires good plant ID skills. It records the presence or absence and kind of cover for a set of specific points along a transect. The results are used to describe soil-water-vegetation relationships (especially in reference to erosion and infiltration) and changes in species composition.

2. Gap Intercept

This method is used to collect data for canopy and basal gaps. It is relatively rapid to conduct and requires no plant ID skills. It measures the percentage of line covered in gaps of predetermined sizes in the vegetative community. The minimum gap size observed is 20 cm, and can be adjusted if needed. The results are used to interpret the potential for wind and water erosion, as well as susceptibility to exotic plant invasion.

3. Herbaceous Plant Production – Double Sampling

This method is used to collect data for annual herbaceous production. It is relatively slow to conduct and requires good plant ID skills. It is based on the establishment of verified weight units, the estimation of number of weight units, and then the destructive sampling of a subset of the estimated plots to validate the estimations. The results are used to describe the community composition, productive capability, energy flow, and herbivore carrying capacity.

4. Supplemental or Experimental Methods

Additional questions regarding vegetation could require data collection methods in addition to the minimum data set (Table 5). Other methods can be proposed to provide other required data or to increase the efficiency of data collection. New methods would initially be conducted along with the standard methods. However, it is conceivable that once a thorough validation is complete, additional methods may be adopted as standards.

**Table 5. Methods and Properties: Grassland, Shrubland and Savanna Ecosystems.**

| **Minimum data set (June, 2008)** | | |
|---|---|---|
| **Field protocol or method** | **Used for** | **Property** |
| Line-point intercept | Soil-vegetation relationships, cover and extent estimates, properties affecting air-soil interface functions (resistance to erosion, infiltration, etc.) | Total canopy (foliar) cover (%)<br>Canopy (foliar) cover by plant functional group (%)<br>Canopy cover by functional group (%) (not foliar)<br>Bare ground (%) (no canopy over no soil cover)<br>Litter cover (%)<br>Biological crust cover by functional group (%) (moss, lichen, dark cyanobacteria, light cyanobacteria)<br>Rock fragment cover |
| Canopy and basal gap intercept (transect) | Wind erosion and exotic plant invasion (canopy); water erosion risk and; infiltration (gap) | Canopy gaps by size (%)<br>Basal gaps by size (%)<br>(Gap sizes: 25-50, 51-100, 101-200, 201-500, 500-1000, >1000) |
| Plant production-herbaceous. Double sampling method | Annual production, soil-vegetation relationships | Annual herbaceous production |
| Plant production-woody | Annual production, soil-vegetation relationships | Annual woody production |
| Resource retention class | Resource retention, soil-plant interactions, grass fragmentation, shrub encroachment | Resource retention class |
| Soil redistribution class | Current or past erosion, resource redistribution | Soil redistribution class |
| Pedoderm/ Soil Crust class | Resistance to erosion, biological crust development | Pedoderm/crust class |
| **Supplemental or experimental properties** | | |
| Belt transect | Detection of changes in species with low cover or density, esp. woody/invasive species | Plant density<br>Plant density by size class |
| Plant species richness | Precise estimates of species richness | Species richness |
| Vegetation structure | Indicator of habitat cover | Visual obstruction<br>Foliage height diversity |
| Tree density | Populations too widely dispersed for belt transects | Plant density<br>Plant density by size class |
| Riparian channel vegetation survey | Documenting vegetation change along streambanks | Canopy (foliar) cover (%)<br>Cover by functional group (%) |
| Riparian channel and gully profile | Where channel morphology is expected to change or gullies are deepening or recovering | Width-depth ratio<br>Bank angle |

**Figure 6. Control Charts for Two Ecological States: Selected Functional Indicators Derived from the Line Point Intercept Method.**

Legend

Each box plot shows high and low plot means as well as mean and median of 3 plots for the black grama grassland state. Solid line = median. Dashed line = mean.
Dashed red line represents 1 plot mean for the shrub-encroached bunchgrass grassland state.

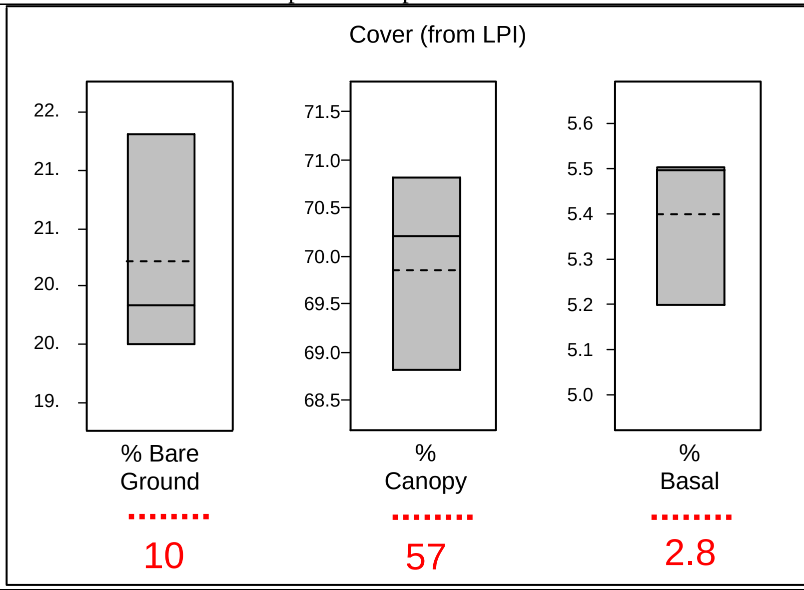


**Table 6. Plot Average of Canopy and Basal Gaps for Two Ecological States.** Mean values are for 3 black grama grassland plots and 1 shrub-encroached bunchgrass plot.

| | | Canopy Gaps | | | | Basal Gaps (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 25-50 cm | 51-100 cm | 101-200 cm | >200 cm | 25-50 cm | 51-100 cm | 101-200 cm | >200 cm |
| **Ecological state** | | | | | | | | | |
| **Black grama** | % of Line | 13.4 | 17.6 | 13.6 | 3.1 | 13.0 | 22.3 | 30.2 | 18.9 |
| **Bunchgrass** | % of Line | 6.5 | 20.6 | 23.9 | 28.1 | 6.9 | 24 | 26.3 | 32.4 |

**Table 7. Annual Production and Foliar Cover for Two Ecological States.**

| | Annual production (%) | | Cover, foliar (%) | |
|---|---|---|---|---|
| **Ecological state** | **Black Grama Grassland** | **Shrub-encroached Bunchgrass** | **Black Grama Grassland** | **Shrub-encroached Bunchgrass** |
| **Source of data** | Ecosite description, aggregate data | 1 plot mean | Summary of 3 plot means | 1 plot mean |
| **Species** | | | | |
| Black grama | 26 | 4 | 58.8 | - |
| Spike dropseed | 17 | 14 | | 22.0 |
| Sand dropseed | | | 0.8 | |
| Mesa dropseed | | | 0.6 | |
| Bush muhly | 7 | 6 | | - |
| Bristlegrass | 3 | 6 | | - |
| Cane bluestem | 7 | - | | - |
| Arizona cottontop | | | | |
| Tobosagrass | 3 | - | | - |
| Threeawn | 7 | 15 | 2.7 | 4.6 |
| Blue grama | 3 | 1 | | |
| Low woollygrass | | | | 1.4 |
| Lehmann lovegrass | - | 8 | | 3.0 |
| Mexican panicgrass | - | 2 | | |
| Vine mesquite | | | | - |
| Longleaf jointfir | 7 | 1 | | |
| Soaptree yucca | | | 0.6 | - |
| Sand sagebrush | 3 | - | | |
| Fourwing saltbush | | | | |
| Winterfat | | | | |
| Broom dalea | | | | - |
| Plains pricklypear | 2 | - | | 7.0 |
| Broom snakeweed | 2 | 15 | 3.7 | - |
| Mesquite | - | 2 | 1.1 | 0.4 |
| Croton | 4 | 4 | 0.2 | |
| Buckwheat | | | | |
| Spurge | | | | |
| Globemallow | | | | 4.6 |
| Desert marigold | | | | |
| Touristplant | | | | |
| Redstem stork's bill | | | | - |
| Dwarf desert peony | | | | |
| Milkvetch | | | | |
| Lamsquarters | | | | |
| Herb Sophia | | | | |
| Russian thistle | | | | |
| Threadleaf ragwort | | | | |
| Silverleaf nightshade | | | 0.1 | 4.0 |
| Other forbs | 3 | 2 | 0.5 | |
| Annual grass (unident.) | | | 0.3 | |
| Fuffgrass | | | 0.2 | |
| Dead grass (unident.) | | | 0.2 | |
| Desert holly | | | 0.2 | |
| Dead shrub (unident.) | | | 0.1 | |

# Wednesday - Agronomy Tour

***Pecan trees are native to the Mississippi River Valley and probably first arrived in New Mexico along with American settlers around the turn of the 20th century. Fabian Garcia, the first director of the New Mexico Agricultural Experiment Station, planted some of New Mexico's first pecan trees in the Mesilla Valley in 1913. Many of these original trees are still standing at New Mexico State University's Fabian Garcia Horticultural Science Center.***

(http://aces.nmsu.edu/ces/pecans/pecan-history.html)

# Station 1- Soil Health and Soil Quality - A National Perspective

## USDA-NRCS and Soil Quality at the National Level

### What is Soil Quality?

Soil quality is defined as ‘the capacity to function’ (Karlen et al., 1997). Dynamic soil quality refers to the effects of management practices on soil function. Soil or ecosystem function is defined in various ways. Some important soil functions (or services) include: water and solute retention and flow, physical stability and support; retention and cycling of nutrients; buffering and filtering of potentially toxic materials; and maintenance of biodiversity and habitat (Daily, 1997). Although dominated by soil scientists, the study of soil quality is largely an ecological endeavor due to its ultimate concern with ecosystem function.

Historically, productivity is has been used as the only measure functional performance. However, in highly managed systems, this function could be subsidized with external resources to the point where it is not actually indicative of the ecosystem’s health or soil’s true ability to function. Larson and Pierce (1991) argued that soil quality should no longer be limited to productivity, inferring that the sole emphasis on productivity may have contributed to soil degradation in the past. Soil quality (SQ) assessment is one area of agricultural research that attempts to estimate performance of multiple essential soil functions (e.g., Larson and Pierce 1991; Doran and Parkin, 1994; Andrews et al., 2004).

In order to address the emerging need to address the full spectrum of soil functions at the national level, NRCS created the Soil Quality Institute 1995-1994; then March 1995, the National Soil Quality Technology Development Team was formed.

## The NRCS National Soil Quality Technology Development Team (SQ NTDT)

### Background

**_Our Vision_**

Healthy ecosystems built on a foundation of well-functioning, high quality, productive soils

**_Our Mission_**

Cooperate with partners in the development, acquisition and dissemination of soil quality technology and training to help people conserve and sustain our natural resources and the environment

Soil is the foundation for other natural resources. The quality of soil directly impacts water and air quality as well as food quality; indirectly, it affects wildlife habitat and animal and human health. The concept of soil quality and the understanding of how soils function to enhance other resources and provide ecosystem services have the potential to raise the bar for natural resource conservation by recognizing these interactions and managing for them. Dynamic soil quality must be understood as human-induced soil change and interpreted within the context of inherent soil properties and management history. The complex issues affecting soil quality require a multidisciplinary approach to include soil scientists, ecologists, agronomists, range specialists and others. The main contributions of soil quality to soil science, soil survey and resource conservation are:

- Recognition of the importance of dynamic soil properties, especially soil carbon, and indicators of soil function that move beyond managing for “T.”
- Promotion of soil function and ecosystem service concepts can lead producers to reduce costly and limited petroleum based inputs, including fuel use and effective pest and nutrient management strategies.
- Bringing soil biology to the fore (on par with soil chemistry and physics), providing a more complete picture of soil properties and processes.
- The focus on dynamic soil change exemplifying the need for land use- and management-specific interpretations for soil properties (i.e., a soil change properties database as part of NASIS)
- The application of ecological concepts, such as function and thresholds, allowing for a view of soils as a vital part of ecosystems, including limits to soil resistance and resilience.
- Provision of a holistic framework for decision making and conservation planning at multiple scales and land uses.
- The creation and dissemination of simple tools for assessment and monitoring, such as the Health Card, SQ Test Kit or Soil Management Assessment Framework, and simple models, such as the Soil Conditioning Index (SCI), and practice-based eligibility tools, such as the Conservation Management Tool.
    - comparing alternative practices or systems
    - allowing for quantification of conservation practice effects, and

- providing measurable targets for resource quality criteria and remediation.

**National Soil Quality Team Partners and Customers**

To accomplish our mission the SQ NTDT will partner with universities, organizations and agencies to develop and accelerate transfer of soil quality technology and training to facilitate natural resource conservation and promote ecosystem health. Our primary customers are NRCS field office and state offices. National Headquarters, other agencies, universities and the public are also assisted as requested. Internal partners include (but are not limited to) other Technology Development Teams and National Technology Support Center staff, National Soil Survey Center, Resource Inventory and Assessment Division, Ecological Sciences Division, Plant Materials Centers, National Geospatial Data Center, State Staffs and local field offices. External partners include universities, ARS, SWCS, National Park Service, Forest Service, and others.

**Technical Excellence:**

Technology acquisition and development are needed to improve NRCS technical capacity in resource assessment (for program eligibility and accountability), conservation technical assistance, and program implementation. The Soil Quality Team (SQT) will pursue technologies in five main areas: 1) resource assessment models; 2) in-field assessment tools; 3) soil dynamic properties inventory; 4) adoption of soil-building practices; and 5) conservation planning tools. **The development of any and all such tools must be accompanied by validation and calibration efforts to uphold NRCS's reputation for scientifically-defensible technical excellence.**

*1) Resource Assessment Modeling*: Additional efforts are needed in modeling conservation practices and practice interactions to predict changes in soil, water and air quality and the economic impacts thereof.

- *Conservation Effects Assessment*: is needed to improve NRCS program funding accountability. The Soil Quality Team will help with model interpretation for the Conservation Effects Assessment Project (CEAP), as the co-lead for the National Soil Quality Assessment Project. These efforts have several potential applications in addition to their planned practice effects assessment, including: creation of a dynamic soil properties database, provision of baselines for CSP enhancement standards, and development of guidelines for residue harvest.
  - Collaborate with Soil Science and Resource Assessment Deputy Area on the development of interpretation curves for EPIC model output.
  - Collaborate with USDA-ARS on the testing and development of the Soil Management Assessment Framework (SMAF), a tool for site-specific soil assessment. ARS has adopted the tool as part of its Soils National Program (202). It was designed for use with measured soil properties, as such has potential for use with CSP enhancements and the watershed portion of CEAP. It is being modified for use with model output for the national level CEAP.
- *Assessment of NRCS Carbon Modeling Needs*: Currently, NRCS is using or pursuing the development of at least 5 different carbon models. These various

groups are not in communication with each other. The agency would be better served if model development was done after careful assessment of needs and uses. The SQT will lead a consensus building project to identify NRCS' carbon modeling needs, culminating in a white paper, in collaboration with the Air Quality and Atmospheric Change NTDT and others.

- *Development and Validation of Program Eligibility Tools*: The SQT is currently collaborating on the development of the Conservation Measurement Tool, which will serve as an eligibility tool for the Conservation Stewardship Program. The SQ NTDT is also collaborating on two CESUs with university partners: 1) to help validate the tool by comparison with measured and modeled data and 2) to capture farmer's perceptions of understandability, fairness and equity of the tool.
- The SQ NTDT with explore partnerships with the Land Institute, Rodale Institute and Dakota Lake Research Center for improving the crop diversity index model for improving soil function. Improving crop diversity will reduce chemical inputs.

*2) In-field Assessment*:
The soil quality test kit is one of the most used products of the former SQ Institute. The simple, in-field tests contained in the kit make it attractive for field office use. It has value as an educational tool to demonstrate to landowners the impact their management choices have on soil function. These assays can also be used to evaluate quality criteria for not only soil, but also water, air, and wildlife (soil biota). However, since the kit was first developed, new methods have emerged with potential to greatly enhance the value of the kit for: field staff tools for assessment and land-owner education; Resource Quality Criteria; CSP enhancement measures; soil survey/dynamic properties database additions; criteria for practice standard revisions (e.g., tillage standards); and restoration assessment tools. The SQT will investigate these methods, and when appropriate, accelerate their development to include transfer of this technology to field and state offices.

- *Collaborate on the development of an in-field carbon assessment too with agency and university partners. Promising technologies include*:
  - Permanganate Oxidation (Active C) methodology development
  - decomposition incubation strips
  - Soil Color via data mining
- *Investigate in-field indicators for water relations*, to improve the functionality of pedo-transfer functions being developed by NSSC staff, to include:
  - *Explore adaptations to the Cornell Infiltrometer (for surface) and Amoozemeter (for subsurface)* as in-field measures of infiltration and/or aggregate stability.
  - *Collaborate on the development of an in-field dry aggregate stability* as an indicator for wind erosion potential
- *Collaborate on the development of in-field enzyme assays for biological activity and active carbon*
- *Partner with National Park Service, Plant Materials Centers, Manure Management NTDT and others on the development of soil quality assessment tools and methods for restoration and remediation.*

*3) Soil Change and Dynamic Soil Properties Database Development*: The NSSC has been charged with development of a dynamic properties database. This is needed because the ranges found for various soil properties encompass all land uses, making them so broad as to render them meaningless in many cases. Current research shows that different soils under similar management become more similar over time, due to human management acting as a sixth soil forming factor. Soil quality is concerned with soil change as a result of management. The appropriate design and implementation of the database will require input from soil quality experts.

- The SQ NTDT will collaborate with SSD as part of their DSP Leadership and Technical Leads teams for:
  - identification of resource concerns related to near-surface properties in-field sampling methodology development
  - database design, and
  - property interpretations, among other needs.
- The SQ NTDT will take leadership responsibility for the development of a cross-section working group for the Soil Science Society of America to explore knowledge gaps in soil change technology and information.
- The SQ NTDT is also co-lead in the development of a Soil Change Working Group for the National Cooperative Soil Survey, meeting for the first time at the Las Cruces Conference.

*4) Adoption of Soil-building Conservation Practices*: Basic practices for improving soil quality, such as Tillage & Residue Management, Conservation Crop Rotations, and Cover Crops, are well known but often underutilized. Barriers to adoption of these technologies vary by practice, region and individual land manager. Often the barriers are economic or social, such as attitude, traditional bias, perceived costs, length of return on investments, or land tenure. Other barriers include lack of knowledge about the specifics on how to implement the practice, e.g., dealing with cold, wet soils, irrigation systems (furrow), managing residues, planters, seeding rates, planting dates, and rotations etc. Opportunities and challenges in dryland and irrigated cropland, organic agriculture, pasture, rangeland, urban, prairie, and forested systems should be explored. The SQT will partner with researchers in soil science, agronomy, social science and economics to investigate and eliminate these barriers to adoption via applied research collaborations; on-farm trials; marketing; and other techniques as needed. This will be accomplished primarily via technical collaborations on Conservation Innovation Grants and via updates to the following guidance documents:

  - National Practice Standards, in which soil conservation or soil quality is a purpose (or a consideration), in collaboration with the National Agronomist
  - Conservation Practices Physical Effects document via review for appropriate consideration of soil quality criteria

*5) Conservation Planning Tools:* Currently, NRCS works toward maintaining or enhancing soil quality through the use of RUSLE2 technology, to meet T. While this is an important part of soil conservation, our efforts could be improved by adding tools that consider soil carbon, such as the Soil Conditioning Index (SCI). The Soil Quality Team will work to streamline consideration of soil quality in conservation planning by:

- Collaborating with Programs Deputy Area to report the outcomes of new CMT or other assessment tools.

- Continually evaluating new practices for their effect on soil quality and accelerating the development of new standards, when appropriate. One example is roller-crimper technology.
- Accelerating the development and use of crop diversity indices for cropland.
- Collaborating with ARS on the development of guidelines for residue removal. DOE and associated industries currently plan to use corn stover and wheat straw as cheap feedstocks for bioenergy production. The removal of these crop residues has major potential to degrade the soil. Development of guidelines for this practice may help reduce this problem.

**What are the current challenges to SQ?**

**1) How to Assess Soil Quality at Different Spatial Scales**

Across many disciplines, there is recognition that complex spatial and temporal dynamics must be addressed for effective resource assessment and management (e.g., Christensen et al., 1996; Herrick et al., 2002). Systems approaches and hierarchical organizational tools can help scientists and managers deal with complexity in soil ecosystems (Carter et al., 2003). According to Norton (1992), hierarchical environmental management is necessary because, “Processes are not related equally but unfold in systems within systems, which differ mainly regarding the temporal and spatial scale on which they are organized.” Using a hierarchical systems approach may also help soil scientists relate dynamic soil changes to broader system outcomes, such as changes in air or water quality.

All systems exhibit hierarchical organization (Allen & Starr, 1982; O’Neill et al., 1986; Stephens and Hess, 1997). C.R.W. Spedding (1988), one of the earliest adopters of systems thinking in agriculture, offered the following definition:

> “A system is a group of interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli: it is unaffected directly by its own outputs and has a specified boundary based on the inclusion of all significant feedbacks.”

Ellert et al. (1997) and Gliessman (1998) argue that an understanding of these system interactions and properties is prerequisite to effective agroecosystem management. (If you question the validity of this approach for soil science, substitute the word ‘soil’ for ‘system’ in the above definition.)

While there has been much debate about whether hierarchies are a human construct or a true phenomenon (Allen and Starr, 1982), the ability to organize our thinking into spatio-temporal units has clear benefits for research, inventory, and management, including understanding soils, their position in the landscape, and the changes with time under a variety of land use and management practices.

Hierarchical systems constructs can naturally navigate the complex issues of scale, in large part because temporal and spatial scales usually coincide. Spatially larger processes often require longer time periods compared to spatially smaller ones. Ellert et al. (1997) define the relationships between spatial and temporal scales for a variety of soil systems, subsystems and components, illustrating this proportionality between space and time for soils.

As a result of this relationship, different management approaches or practices may require different levels of systems analysis for assessment of sustainability or quality. For example, soil biophysical processes are often defined at the field level, while rotational cropping might be assessed at a field or farm level using a time scale at least equivalent to the rotation length. Filter strip systems probably need to be assessed at a watershed or regional level at a time scale long enough to allow species establishment and account for precipitation variability. Microeconomics would be properly addressed at the farm level. A watershed or regional level analysis would be appropriate to examine macroeconomic sustainability (Lowrance, 1990).

**2) Soil Quality Interpretations**

We recognize sustainable management practices as site- or system-specific. Therefore, conservation alternatives must be compared for each system at a variety of hierarchical levels. Because appropriate scale is essential to assessment, inventory, and management of system processes and functions, many authors suggest a systems-based approach to understanding and managing agroecosystems (Hart, 1984; Lowrance et al., 1987) and the inherent soil properties that comprise their foundation (Carter et al., 2003).

Ellert et al. (1997) conclude that using a systems approach: 1) places soil within a larger ecosystem; 2) recognizes a broad array of support services or soil functions (beyond crop production); 3) incorporates humans as internal controllers; 4) allows for multiple management goals including production, conservation and aesthetics; and 5) uses integrative science to identify possible pathways to sustainability. It is necessary to utilize these approaches such that each hierarchical level of an agroecosystem, from soil to region, is adaptively managed to meet the multiple goals of conservation ecosystem sustainability.

## a) Assessment and Inventory Methods

One way to interpret soil properties as indicators of soil function is through the use on non-linear scoring curves. Non-linear scoring techniques involve the use of curvilinear algorithms with an x-axis representing a site-specific range for the given indicator and a y-axis representing performance of ecosystem function (Karlen and Stott, 1994). This type of scoring is used widely under various guises in economics as utility functions (Norgaard, 1994), multi-objective decision making as decision functions (Yakowitz et al., 1993), and systems engineering as a tool for modeling (Wymore, 1993). The NRCS-NSSC's National Soil Information System (NASIS) also uses a non-linear scoring system as part of its fuzzy logic backbone. This method requires in-depth knowledge of each indicator's behavior and function within the system.

Many researchers have used non-linear scoring to quantify the effects of management on soil function. Andrews and Carroll (2001) used scoring curves to compare alternative poultry litter amendments to fescue pastures. Karlen et al. (1998) used weighted scores to assess land coming out of the Conservation Reserve Program (CRP). Hussain et al. (1999) also used scoring curves to compare tillage systems. Yakowitz et al. (1993) used non-linear scoring to compare the overall effects of alternative farming systems. Inventory will be assess in depth during the soil change field trip and therefore not specifically addressed here.

## b) Field –Scale Site-specificity or Tool Transferability

Some efforts have been made to assess the site-specificity and transferability of scoring curves. For example, Hussain et al. (1999) and Glover et al. (2000) adjusted the index weighting and indicator threshold values to be applicable to their respective systems. Andrews and Carroll (2001) also shifted the expected ranges for indicators between sites.

A tool under continued development, the Soil Management Assessment Framework, was shown to improve the interpretation ability of scoring curves (Andrews et al. 2004). As before, the shape of an indicator's scoring curve (or algorithm) is dictated by the relationship between the indicator and the soil function. However, the expected range for each indicator is determined using site-specific factors, such as crop, climate or soil type. Changes in expected range due to site-specific differences result in automatic parameter shifts in the scoring curve (Figure 1).

Comparisons of scored indicators' ability to explain variation in performance outcomes for four case studies across the U.S. were performed. Results showed good ability of the scored indicators to represent (often difficult to measure) performance outcomes. For example, scored indicator-endpoint regressions for the Iowa case study had $R^2$ results of 0.99, 0.84, and 0.61 with sedimentation in surface water, atrazine applied, and crop yield, respectively (Andrews and Karlen, manuscript in preparation). This test seemed to confirm that the new scoring method was capturing intended information about the soils' performance of ecosystem functions. It has been used in various studies since then as well (e.g. Cambardella et al., 2004; Karlen et al., 2006; Wienhold et al., 2006;). This tool has also been used to interpret model data for CEAP (Potter et al., 2006). Next steps include new curves for additional soil properties (Wienhold et al., review; Stott et al., in review), potential application of the method for dynamic soil properties interpretation in soil survey, and further use in the CEAP efforts.
Website and Excel format versions for the scoring framework are available for review (contact S. Andrews at susan.andrews@gnb.usda.gov). An interactive website is still under construction but can be viewed and tested at http://soilquality.org .

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# Station 2 - Soil, Water, and Plant Analysis in Conservation Planning

## New Mexico Sustainable Agriculture Producer Guide

The Natural Resources Conservation Service, formerly the Soil Conservation Service, works hand-in-hand with the American people to conserve natural resources on private lands.

THE USDA IS AN EQUAL OPPORTUNITY PROVIDER AND EMPLOYER

# Purpose of NM Integrated Water Management Handbook:

**http://www.nm.nrcs.usda.gov/technical/handbooks/iwm/nmiwm.html**

Irrigation water management is an integral part of a complete farming system of soil, water, air, plant, animal, and human resources. The New Mexico Integrated Water Management Handbook is intended to be user friendly for use by planners with producers. It provides guidance on "how-to" evaluate and understand site-specific field conditions, including chemical, biological and physical. This enables us to evaluate and implement best management practices/approaches for cropland management within an integrated farming system. Considering how the farm fits into broader watershed management (e.g. off-site effects and resource opportunities) is also essential to problem-posing and problem-solving resource management success.

The Natural Resources Conservation Service provides technical assistance for producers in all aspects of cropland conservation, including irrigation water management (e.g. installation of irrigation water management practices, water measuring, irrigation scheduling, irrigation system design, reduced cultivation), and nutrient management (e.g. soil, water, and plant nutrient analysis, developing basic nutrient budgets, and determining appropriate fertilizer and manure applications). Other technical assistance areas have included agronomic-related practices and management such as reduced tillage, crop rotations, green manure crops, cover crops, salinity and integrated pest management. This Handbook provides guidance on understanding and improving soil quality, water quantity/quality, air quality, nutrient and salinity management, crop yield and quality, irrigation water management, integrated pest management. It also provides guidance on reducing overall on-farm energy use, inputs, production costs, pest incidences, pumping costs, as well as soil and water losses. The end result targets becoming a more economical, sustainable farming enterprise, including resource efficient and resource conserving.

The key approach to achieving integrated sustainable management is to think system (ecosystem, whole farm, and watershed wh think cr

## Potential Benefits of Integrated Water Management

Water resource:

- Conserves surface and ground water supplies
- Protects surface and ground water quality
- Substantial reduction in irrigation labor costs
- Significant increase in irrigation application efficiencies (higher yields)
- Reduced pumping costs
- Potential detrimental effects of water quality (pH, salinity & sodium) on plants and soils are properly assessed and managed for
- Irrigation water losses through evaporation, runoff and deep percolation are minimized

Soil resource:

- Improved soil quality is possible because of increased biomass production (more crop residues are produced)
- Reduced soil erosion from both water and wind
- Proper assessment, management and prevention of Saline, Saline-Sodic and Sodic soils is attained
- Reduced use of soil amendments
- Reduction in water-logged soils
- Reduced leaching results in higher nitrogen-use efficiency

Plant resource:

- Cost for crop production is reduced due to integration of IWM with nutrient management practices
- Significant increases in yield and crop quality
- Reduced incidences of diseases and pests
- Available water quantity and quality meet the specific requirements of the crop (consumptive use, leaching)

Other:

- Increased beneficial use of fertilizer and soil amendment inputs
- Reduction in over all on-farm energy use
- Protects the environment by the planned judicious use of water, fertilizers and other inputs
- Record keeping is used as an invaluable planning tool in the decision and management of current and future water resources
- All the major aspects involved in the farm operation are integrated in this IWM Handbook
- Analysis of soil, plant/petiole tissue and water samples allows the producer to make informed decisions on all inputs and their relationship to IWM principles
- An effective IWM Plan should be updated to reflect mgmt. changes, learning, etc.

Rudy Garcia 2008

# SQ – 8a. Benefits of Conservation Tillage

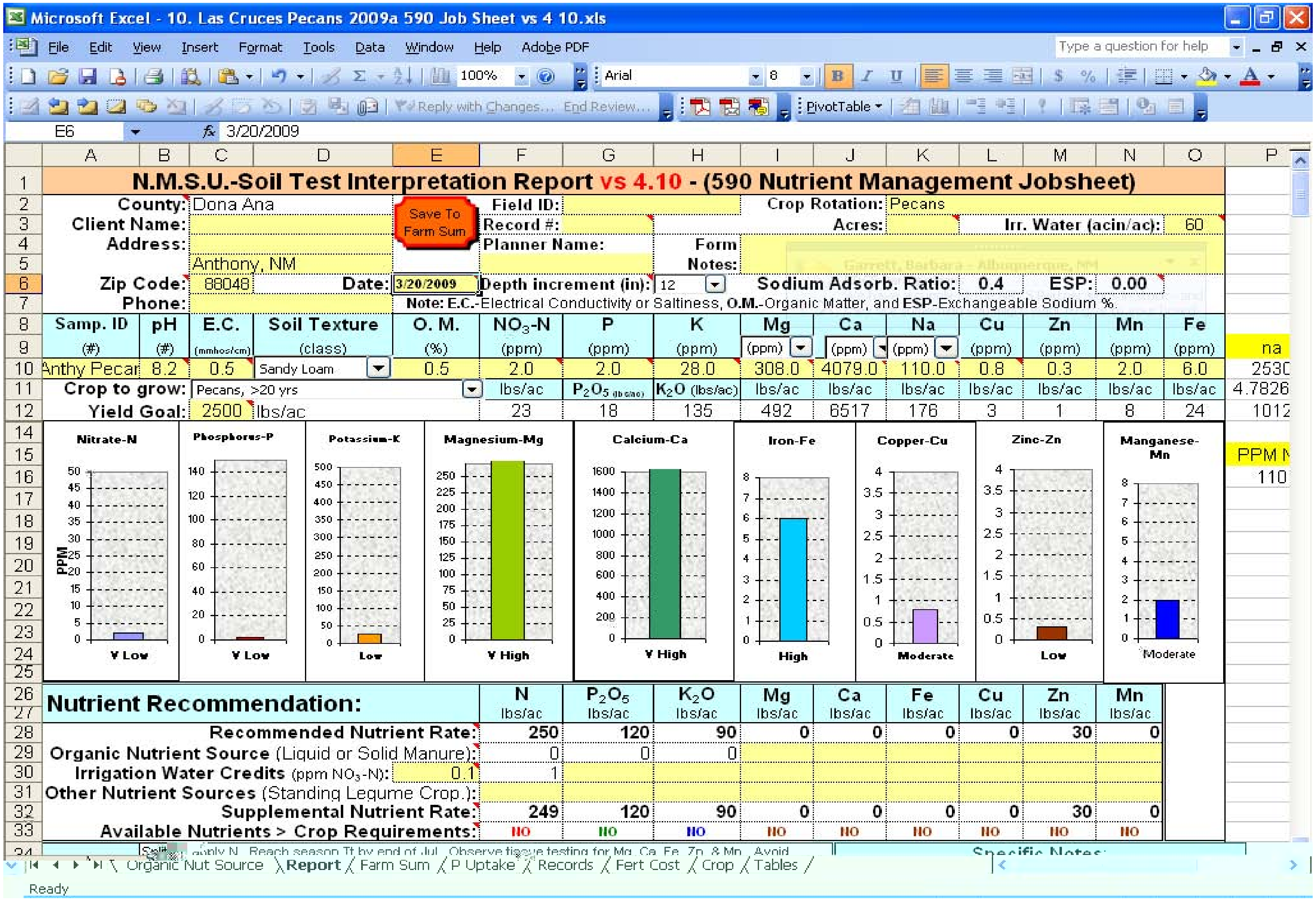
## Environmental:

- Reduces soil erosion from both water and wind ( 90% erosion reduction can be expected when using a no-till instead of intensive tillage system).
- Increases organic matter (each tillage trip oxidizes some organic matter; research shows continuous no-till can increase organic matter in the top 2 inches of soil about 0.1% each year).
- Improves water quality (when combined with irrigation water management, crop nutrient management, integrated pest management, conservation crop rotation, in integrated system, conservation tillage plays an important role in improving both runoff to streams, rivers, and lakes as well as water that finds its way into aquifers).
- Improves wildlife habitat (the crop's residue provides food and shelter. In addition, if combined with other needed habitat, such as grassy cover and woody areas, wildlife may increase significantly).
- Other benefits include reduced soil compaction, utilization of marginal land, some harvesting advantages, and conservation compliance.

## Economic:

- Yields are good, if not better, than reduced or intensive tillage system when managed properly.
- Optimizes soil moisture (improved infiltration and increased organic matter are especially important on droughty soils and may help the crop through a persistent dry period. Tillage reduces available moisture by about ½" per trip).
- Saves time (On a 1000 acre farm, an additional 100 hours are needed for every pass (example based on 18' disk, 160 hp FWD). Many growers take advantage of the time savings by exploring other "opportunities").
- Reduces fuel consumption (no-till can reduce fuel use by 3.5 gallons/acre compared to intensive tillage).
- Reduces overall production costs (NMSU reports that irrigated wheat yields in Clovis are comparable between conventional and conservation tillage, but production costs for conservation tillage are lower by as much as $50 per acre).
- Reduces machinery wear (less machinery means fewer pieces need to be replaced. Economists report this amounts to a $5/acre reduction in costs).

Linda Scheffe, 2008




Excel Spreadsheet is used with Practice Code 590 Nutrient Management Job Sheet to record and calculate nutrient status and needs based upon soil analysis, nutrient sources, and crop needs.

# WQ-6 Crop Salt Tolerance Table for NM

## Crop Salt Tolerances

| Crop (name) | Yield loss 0% | | Yield loss 10% | | Yield loss 25% | | Yield loss 50% % | | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | ECe[1] | ECw[2] | ECe[1] | ECw[2] | ECe[1] | ECw[2] | ECe[1] | ECw[2] | ECe[3] |
| Alfalfa | 2.0 | 1.3 | 3.4 | 2.2 | 5.4 | 3.6 | 8.8 | 5.9 | 15.5 |
| Almond | 1.5 | 1.0 | 2.0 | 1.4 | 2.8 | 1.9 | 4.1 | 2.7 | 7.0 |
| Apple | 1.7 | 1.0 | 2.3 | 1.6 | 3.3 | 2.2 | 4.8 | 3.2 | 8.0 |
| Apricot | 1.6 | 1.1 | 2.0 | 1.3 | 2.6 | 1.8 | 3.7 | 2.5 | 6.0 |
| Barley | 8.0 | 5.3 | 10.0 | 6.7 | 13.0 | 8.7 | 18.0 | 12.0 | 28.0 |
| Beans | 1.0 | 0.7 | 1.5 | 1.0 | 2.3 | 1.5 | 3.6 | 2.4 | 6.5 |
| Beets | 4.0 | 2.7 | 5.1 | 3.4 | 6.8 | 4.5 | 9.6 | 6.4 | 15.0 |
| Bermuda Grass | 6.9 | 4.6 | 8.5 | 5.7 | 10.8 | 7.2 | 14.7 | 9.8 | 22.5 |
| Blackberry | 1.5 | 1.0 | 2.0 | 1.3 | 2.6 | 1.8 | 3.8 | 2.5 | 6.0 |
| Broccoli | 2.8 | 1.9 | 3.9 | 2.6 | 5.5 | 3.7 | 8.2 | 5.5 | 13.5 |
| Cabbage | 1.8 | 1.2 | 2.8 | 1.9 | 4.4 | 2.9 | 7.0 | 4.6 | 12.0 |
| Cantaloupe | 2.2 | 1.5 | 3.6 | 2.4 | 5.7 | 3.8 | 9.1 | 6.1 | 16.0 |
| Clover | 1.5 | 1,0 | 2.3 | 1.6 | 3.6 | 2.4 | 5.7 | 3.8 | 10.0 |
| Corn, Grain & Silage | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10.0 |
| Corn Silage | 1.8 | 1.2 | 3.2 | 2.1 | 5.2 | 3.5 | 8.6 | 5.7 | 15.5 |
| Corn, Sweet | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10.0 |
| Cotton | 7.7 | 5.1 | 9.6 | 6.4 | 13.0 | 8.4 | 17.0 | 12.0 | 27.0 |
| Fescue, Tall | 3.9 | 2.6 | 5.8 | 3.9 | 8.6 | 5.7 | 13.3 | 8.9 | 23.0 |
| Grape | 1.5 | 1.0 | 2.5 | 1.7 | 4.1 | 2.7 | 6.7 | 4.5 | 12.0 |
| Lettuce | 1.3 | 0.9 | 2.1 | 1.4 | 3.2 | 2.1 | 5.2 | 3.4 | 9.0 |
| Love Grass | 2.0 | 1.3 | 3.2 | 2.1 | 5.0 | 3.3 | 8.0 | 5.3 | 14.0 |
| Meadow Foxtail | 1.5 | 1.0 | 2.5 | 1.7 | 4.1 | 2.7 | 6.7 | 4.6 | 12.0 |
| Onion | 1.2 | 0.8 | 1.8 | 1.2 | 2.8 | 1.8 | 4.3 | 2.9 | 7.5 |
| Orchard Grass | 1.5 | 1.0 | 3.1 | 2.1 | 5.5 | 3.7 | 9.6 | 6.4 | 17.5 |
| Pear | 1.7 | 1.0 | 2.3 | 1.6 | 3.3 | 2.2 | 4.8 | 3.2 | 8.0 |
| Pecan[4] | 1.9 | 1.3** | 2.4* | 1.6** | 3.2* | 2.4** | 4.6 | 3.0** | 8.0* |
| Pepper | 1.5 | 1.0 | 2.2 | 1.5 | 3.3 | 2.2 | 5.1 | 3.4 | 8.5 |
| Potato, Irish | 1.7 | 1.1 | 2.5 | 1.7 | 3.8 | 2.5 | 5.9 | 3.9 | 10.0 |
| Potato, Sweet | 1.5 | 1.0 | 2.4 | 1.6 | 3.8 | 2.5 | 6.0 | 4.0 | 10.5 |
| Radish | 1.2 | 0.8 | 2.0 | 1.3 | 3.1 | 2.1 | 5.0 | 3.4 | 9.0 |
| Ryegrass, Perennial | 5.6 | 3.7 | 6.9 | 4.6 | 8.9 | 5.9 | 12.2 | 8.1 | 19.0 |
| Safflower | 5.3 | 3.5 | 6.2 | 4.1 | 7.6 | 5.0 | 9.9 | 6.6 | 14.5 |
| Soybean | 5.0 | 3.3 | 5.5 | 3.7 | 6.2 | 4.2 | 7.5 | 5.0 | 10.0 |
| Spinach | 2.0 | 1.3 | 3.3 | 2.2 | 5.3 | 3.5 | 8.6 | 5.7 | 15.0 |
| Sudan Grass | 2.8 | 1.9 | 5.1 | 3.4 | 8.6 | 5.7 | 14.4 | 9.6 | 26.0 |
| Tomato | 2.5 | 1.7 | 3.5 | 2.3 | 5.0 | 3.4 | 7.6 | 5.0 | 12.5 |
| Trefoil, Big | 2.3 | 1.5 | 2.8 | 1.9 | 3.6 | 2.4 | 4.9 | 3.3 | 7.5 |
| Trefoil, Birdsfoot | 5.0 | 3.3 | 6.0 | 4.0 | 7.5 | 5.0 | 10.0 | 6.7 | 15.0 |
| Wheat | 6.0 | 4.0 | 7.4 | 4.9 | 9.5 | 6.4 | 13.0 | 8.7 | 20.0 |
| Wheatgrass, Crested | 3.5 | 2.3 | 6.0 | 4.0 | 9.8 | 6.5 | 16.0 | 11.0 | 28.5 |
| Wheatgrass, Tall | 7.5 | 5.0 | 9.9 | 6.6 | 13.3 | 9.0 | 19.4 | 13.0 | 31.5 |
| Wild Rye, beardless | 2.7 | 1.8 | 4.4 | 2.9 | 6.9 | 4.6 | 11.0 | 7.4 | 19.5 |

[1] ECe is the electrical conductivity of saturated soil extract, reported in millimhos per centimeter at 25°C.
[2] ECw is the electrical conductivity of the irrigation water, reported in millimhos per centimeter at 25°C.
[3] Maximum ECe is the conductivity of saturated soil extract, reported in millimhos per centimeter at 25°C, at which the plant dies.
[4] Complete data is not currently available for pecans. The * is an interpolation between the 0% and 50% range. The ** for ECw is calculated as ECe x 0.67, which is a general rule of thumb for these ratios under average conditions. RDFischer , 2/09

# Station 3 – Soil Quality Test Kit Demonstration

***"The nation that destroys its soil destroys itself"***

- Franklin D. Roosevelt

# Soil Quality Test Kit

**What soil tests are in the kit?**

Measuring soil quality-provides guidelines for sampling and site characterization.

**Soil respiration**-measured using an aluminum cylinder that is 6 inches in diameter and 5 inches long. The cylinder is capped and accumulated carbon dioxide respired by soil organisms and plant roots is measured. Respiration provides a measure of biological activity, which is related to nutrient cycling and breakdown of pollutants in the soil.

**Infiltration**-measured using the same cylinder as in the soil respiration test. Infiltration is important to reducing runoff and storing water in the soil for plant growth.

**Bulk density**-measured by inserting a 3-inch-diameter cylinder 3 inches into the soil surface and removing the intact soil. Bulk density is related to root growth, biological activity, and movement of water and air in the soil.

**Electrical conductivity (EC)-**measured with a pocket EC meter. It provides a measure of salinity (excess salts) in the soil.

**Soil pH**-measured with a pocket pH meter. It relates to nutrient availability and plant growth.

**Soil nitrate-**measured by dipping nitrate test strips into the solution filtered from a 1:1 ratio soil/water mixture. Soil nitrate levels are important for plant growth and water quality.

**Aggregate stability**-determined by sieving soil in water and measuring the amount of aggregates greater than 0.25 mm in diameter that remain on the sieve. Aggregation is important in decreasing erosion, increasing water and air movement, and preserving organic matter in the soil.

**Soil slaking**-determined by putting soil fragments or aggregates in water and estimating the degree of slaking. Slaking is important to reducing erosion and development of surface crusts.

**Earthworms**-determined by counting the number of earthworms found in a square-foot hole. They are important in nutrient cycling and creating large pores for water and air movement in the soil.

**Soil physical observations and estimations**-shows how to observe soil structure and root patterns and to estimate topsoil depth, penetration resistance, and soil texture in the soil profile.

**<u>These properties are important to the physical environment for plant growth.</u>**

**Water quality tests: (**estimates salinity, nitrate and nitrite levels in water).

**Electrical conductivity (EC)**-measured with a pocket EC meter. It provides a measure of salinity (excess salts) in the water.

**Soil pH**-measured with a pocket pH meter. It relates to nutrient availability and plant growth.

**Soil nitrate**-measured by dipping nitrate test strips into the solution filtered from a 1:1 ratio soil/water mixture. Soil nitrate levels are important for plant growth and water quality.

Clarence Chavez, 2009

# Soil Respiration Test:

Full Description of the procedure is at: http://soils.usda.gov/sqi/assessment/files/chpt2.pdf

Simplified version of procedure:

1: Drive Ring into Soil. Make sure that the soil has been wet for at least 6 to 24 hours.
2: Cover the Ring with plastic lid and wait for 30 minutes to allow CO2 to accumulate in the ring.

3. Connect all parts of the Draeger Tube Apparatus.

- Connect the needle to one of the section of plastic tubing.
- On the other end of the same tubing connect the Draeger tub (remember to break open both ends of the Draeger tube before connecting and note that the arrow on the tube points away from the needle).
- Connect the second piece of plastic tubing to the other end of the Draeger tub.
- Connect the syringe to the end of the plastic tubing.

4. Insert the needle on the end of the syringe apparatus in to the stopper on one of the plastic lid on the ring after the 30 minute wait.

- Insert another needle at the other end of the stopper on the plastic lid on the ring. This will create air flow when the syringe is drawn.

5. Start drawing the syringe at a rate of 100cc over a 15 second span.
6. Record the soil Temperature and the percent of CO2.

7. Enter the reading from the Draeger tube apparatus on the data worksheet.
8. Run the Soil Respiration Calculations.

(lb CO2-C/acre/day) = PF x TF x (%CO2 - 0.035) x 22.91 x H

PF = pressure factor = 1

TF = temperature factor = (soil temperature in Celsius + 273) ÷ 273

H = inside height of ring = 5.08 cm (2 inches)

**Soil respiration (lbs $CO_2$-C/a/d)**
**Class Soil condition:**

0.0 - No soil activity Soil has no biological activity and is virtually sterile.

< 9.5 - Very low soil activity
Soil is very depleted of available organic matter and has little biological activity.

9.5 – 16 - Moderately low soil activity
Soil is somewhat depleted of available organic matter, and biological activity is low.

16 – 32 - Medium soil activity
Soil is approaching or declining from an ideal state of biological activity.

32 – 64 - Ideal soil activity
Soil is in an ideal state of biological activity and has adequate organic matter and active populations of microorganisms.

> 64 - Unusually high soil activity
Soil has a very high level of microbial activity and has high levels of available organic matter, possibly from the addition of large quantities of fresh organic matter or manure.

Conversion of Woods End Solvita respiration levels: (mg $CO_2$/kg/wk) x 0.039 x (1.2 g/cm3) x (7.6 cm depth) ÷ 10 x 0.89 = (lbs $CO_2$-C/acre/day). It was assumed all respiration was coming from a 7.6 cm depth with an average bulk density of 1.2 g/cm3 (Doran et al., 1997).

((0.5 X 0.39 X1.2 X7.6) / 10) X 0.89 = 0.015

# Infiltration Test:

Full Description of the procedure is at: http://soils.usda.gov/sqi/assessment/files/chpt3.pdf

**Simplified version of procedure:**

1. Firm the Soil along the inside edges of the 6 inch ring used in the respiration test.
2. Line the inside of the ring with plastic wrap.
3. Pour 444 mL of distilled water (15 oz or 1 inch of water).

4. Remove the plastic wrap (slowly) and record the time.
    - Record the amount of time (in minutes) it takes for the 1" of water to infiltrate the soil.
    - Stop timing when the surface is just glistening.

5. If the soil **was not** at field capacity it is recommended to repeat the infiltration test.
    - In the same ring, perform Steps 2, 3, & 4 with a second inch of water.
    - On the Soil Data worksheet, enter the number of minutes elapsed for the second infiltration measurement.

Note: A second respiration measurement will be performed, set the lid loosely on the ring and leave it covered for preferably 16 to 24 hours (6-hour minimum) before beginning the second test (Chapter 2). (Remove lid and replace it before beginning the second soil respiration measurement).

# Bulk Density Test:

Full Description of the procedure is at: http://soils.usda.gov/sqi/assessment/files/chpt4.pdf

**Simplified version of procedure:**

1. **Drive Ring into Soil**
   - Using the hand sledge and block of wood, drive the 3-inch diameter ring, beveled edge down, to a depth of 3 inches .
   - The exact depth of the ring must be determined for accurate measurement of soil volume. To do this, the height of the ring above the soil should be measured. Take four measurements (evenly spaced) of the height from the soil surface to the top of the ring and calculate the average. Record the average on the Soil Data worksheet.

2. Dig around the ring.
3. With the trowel underneath it, carefully lift it out to prevent any loss of soil.
4. Remove excess soil from the sample with a flat bladed knife.
5. The bottom of the sample should be flat
6. and even with the edges of the ring

Note: the remainder of the procedure should be done in a lab or office or home.

7. Weigh the soil sample in its bag.
8. Extract Subsample to Determine Water Content and Dry Soil Weight.
   - Take a 1/8-cup level scoop subsample of loose soil (not packed down) from the plastic
   - Bag and place it in a paper cup (a glass or ceramic cup may be used).
9. Weigh and Record Subsample in its cup. (also weigh the cup w/o subsample) and record.

10. Dry the subsample in a microwave.
    - Two or more, four minute cycles at full power.
    - When its weight does not change after a drying cycle, then it is dry.

11. Calculations (see page 13) in the soil quality test kit guide.

| Soil texture | Ideal bulk densities (g/cm3) | Bulk densities that may affect root growth (g/cm3) | Bulk densities that restrict root growth (g/cm3) |
|---|---|---|---|
| sands, loamy sands | < 1.60 | 1.69 > | 1.80 |
| sandy loams, loams | < 1.40 | 1.63 > | 1.80 |
| sandy clay loams, loams, clay loams | < 1.40 | 1.60 > | 1.75 |
| silts, silt loams | < 1.30 | 1.60 > | 1.75 |
| silt loams, silty clay loams | < 1.40 | 1.55 > | 1.65 |
| sandy clays, silty | < 1.10 | 1.49 > | 1.58 |
| clays, some clay loams (35-45% clay) clays (> 45% clay) | < 1.10 | 1.39 > | 1.47 |

Soil bulk density can serve as an indicator of compaction and relative restrictions to root growth

**Note: soils with rock fragments have their own procedure.**

# Electrical Conductivity Test

Full Description of the procedure is at: http://soils.usda.gov/sqi/assessment/files/chpt5.pdf

Electrical conductivity, pH, and soil nitrate are all measured from the same soil subsample

Pocket Meter for Electrical Conductivity (EC)

Pocket Meter for pH

**Simplified version of procedure:**

1. Collect a 1/8 cup of the soil surface.
   - Place it in the plastic container.

2. Add 1/8 cup of distilled water to the plastic container.
   - Put the lid on the container and shake vigorously about 30 to 45 seconds.

3. Insert the EC pocket meter into the soil-water mixture. (**See Calibration Tip).**
   - Take the reading while the soil particles are still suspended in solution
   - Do not immerse the meter above the immersion level.
   - Allow the reading to stabilize.

4. Turn the meter off and thoroughly rinse the meter with distilled water.
   - Save the soil-water mixture for the pH measurement

**Note: This test can also be performed on irrigation water samples.**

| EC (dS m-1 at 25 C) | Salinity class | Crop response | Microbial response |
|---|---|---|---|
| 0 - 0.98 | Non saline | Almost negligible effects | Few organisms affected |
| 0.98 - 1.71 | Very slightly saline | Yields of very sensitive crops restricted | Selected microbial processes altered (nitrification/de-nitrification) |
| 1.71 - 3.16 | Slightly saline | Yields of most crops Restricted | Major microbial processes influenced (respiration/ ammonification) |
| 3.16 - 6.07 | Moderately saline | Only tolerant crops yield satisfactorily | Salt tolerant microorganisms predominate (fungi, actinomycetes, some bacteria) |
| > 6.07 | Strongly saline | Only very tolerant crops yield satisfactorily | A select few halophytic organisms are active |

# Soil pH Test

Full Description of the procedure is at: http://soils.usda.gov/sqi/assessment/files/chpt6.pdf

**Simplified version of procedure:**

1 Collect a 1/8 cup of the soil surface.
- Place it in the plastic container.

2 Add 1/8 cup of distilled water to the plastic container.
- Put the lid on the container and shake vigorously about 30 to 45 seconds.

3. Insert the pH pocket meter into the soil-water mixture, (**See Calibration Tip).**
- Take the reading while the soil particles are still suspended in solution
- Do not immerse the meter above the immersion level.
- Allow the reading to stabilize.

5. Turn the meter off and thoroughly rinse the meter with

**Note: this test can also be done on irrigation water samples.**

# Soil Nitrate Test ($NO_3^-$)

Use the same sample prepared for the EC and pH tests to measure soil nitrates. **If you are starting with a fresh soil sample, read the introduction and follow Steps 1-3 in the EC Test Chapter on preparing the sample.**

Full Description of the procedure is at: http://soils.usda.gov/sqi/assessment/files/chpt7.pdf

**Simplified version of procedure:**

1. Fold the filter paper in half (into a cone).

2. Open the filter paper into the shape of a cone and push it quickly into the jar with the soil/water mixture.

3. **Wait** until about an eye dropper full of the solution has seeped through to the inside of the filter paper.

4. Using the eye dropper and on nitrate/nitrite test strip, place 1 or 2 drops of the filtered solution on each of the strips two pads. Note the time.

5. Record the time, after 60 seconds read the nitrate/nitrite test strip.
    - Estimate the nitrate amount according to the degree of color change.
    - Enter the value from the nitrate scale on the Soil Data worksheet in ppm

6. Using the value in ppm in the for Calculation (page 17 of the guide book).

**Estimated** (lb NO3-N/acre) =

$$\frac{\text{(ppm extract NO3-N) x (depth of soil sampled in cm) x bulk density x 0.89}}{10}$$

**Note: this test can also be done on irrigation water samples.**

**Generalized soil nitrogen cycle:**

# Aggregate Stability

Full Description of the procedure is at: http://soils.usda.gov/sqi/assessment/files/chpt7.pdf

**Simplified version of procedure:**

**Considerations:** If the soil is moist, air-dry a sample before determining aggregate stability. When taking a soil sample, care should taken not to disrupt the soil aggregates.

1. Sieve an air dry soil sample.
   - Put about ¼ cup of soil in a 2mm sieve and shake
   - collecting the soil that is passing through.
   - Try and pass all of the soil particles. (no rock fragments).

2. weigh the sieved soil sample.
   - Record the weight on the worksheet

3. Weigh out 10 grams of the soil from the previous step.
   - Place the soil sample in the .25mm sieve.
   - Lay a terry cloth sheet with distilled water
   - Slow the soil to wet up slowly, wet the soil for five minutes.

4. Using the lid to the plastic container, place the sieve's with soil in to it.
   - Add distilled water to just above the soil sample.
   - Slowly move the sieve up and down in the water
   - Make sure the aggregates remain immersed in water on the upstroke.
   - After wetting, place the sieves on a dry terry cloth.

6. Place the sieve containing the aggregates on the drying apparatus
   - Allow the samples to dry using the low power setting.
   - Be careful when drying the soil to prevent particles from blowing out of the sieve.

7. After drying, weigh the sieve containing the aggregates.
    - Weight of the sieve and aggregates / recode the weight.

8. Prepare the calgon solution
    - Calgon solution: put about 2 tbsp of calgon per 1/2 gallon of tap water. (Or about 1/2 tbsp of calgon per 1 quart of tap water).
    - Let the aggregates in the sieve to soak for five minutes,
    - Moving the sieve up and down.
    - Only the sand particles should remain in the sieve.

9. Remove the excess water by first placing the sieve with the sand on a dry terry cloth.
    - Allow the sand to dry.
    - After drying, weigh the sieve containing the sand.
    - Record the weight of the sieve plus sand on the worksheet.

10. Complete the water stable aggregate calculations.

Table 8:

| Organic Matter (%) | Water Stable Aggregates (%) | Clay (%) | Water Stable Aggregates (%) |
|---|---|---|---|
| 0.4 | 53 | 5 | 60 |
| 0.8 | 66 | **10** | 65 |
| 1.2 | 70 | 20 | 70 |
| **2** | 75 | 30 | 74 |
| 4 | 77 | 40 | 78 |
| 8 | 81 | 60 | 82 |
| 12 | 85 | 80 | 86 |

Example: A soil with **2**% organic matter and **10**% clay, the suitable aggregate stability range (taken from Table 8) would be 65 to 75% water stable aggregates.

# Slake Test

Full Description of the procedure is at:
http://soils.usda.gov/sqi/assessment/files/chpt9.pdf

**Simplified version of procedure:**

Considerations: The soil should be Air-Dry when running this test.

1. Carefully remove soil fragments or aggregates (little clods or ped) from the surface.
    - If there is a surface crust, carefully sample it.
    - Be careful not to shatter the soil fragments or ped's while sampling.
    - Collect 16 separate soil fragments/peds/clods.

2. Remove the baskets from the stability kit and set aside.
    - Fill the compartments in the box with water.
    - The water should be 2 cm deep
    - The temperature of water should be the same as the soil temperature.

3. Place soil fragments in the basket one at a time.
    - Lower one of the sieves into the box compartment filled with water.
    - Notice the soil fragment for five minutes.
    - After five minutes, raise the basket out of the water.
    - Then lower it back in to the bottom of the box compartment filled with water.
    - Repeat immersion four times (total of five immersions).
    - Refer to the stability class table below to determine classes…

| Stability Class | Criteria for assignment to stability class (for "Standard Characterization") |
|---|---|
| 0 - | Soil too unstable to sample (falls through sieve). |
| 1 - | 50 % of structural integrity lost within 5 seconds of insertion in water. |
| 2 - | 50 % of structural integrity lost 5 - 30 seconds after insertion. |
| 3 - | 50 % of structural integrity lost 30 - 300 seconds after insertion or < 10 % of soil remains on the sieve after 5 dipping cycles. |
| 4 - | 10 - 25% of soil remaining on sieve after 5 dipping cycles. |
| 5 - | 25 - 75% of soil remaining on sieve after 5 dipping cycles. |
| 6 - | 75 - 100% of soil remaining on sieve after 5 dipping cycles. |

# Earthworms

Full Description of the procedure is at: http://soils.usda.gov/sqi/assessment/files/chpt10.pdf

**Simplified version of procedure:**

**Considerations:** When examining the soil for earthworms, avoid places where their populations might be affected, such as near mulch or compost piles. The abundance of earthworms is usually patchy within a field and varies with season. Therefore, count earthworms several times during a season and use the average to gauge changes from year to year.

1. Dig a soil pit, about 12 inches wide, 12 inches long and 12 inches deep.
    - Try to minimize the number of cuts with the shovel to avoid damage to the earthworms.
    - Pile the soil to one side of the hole/pit.

2. Separate and count the number of earthworms.
    - Record the total number of earthworms (those found in the hole).
    - You could also use a mustard solution to flush out any additional earthworms
    - Mustard solution ( 2 tbs., of mustard powder in ½ gallon of tap water).
    - If you use the mustard solution, you should rinse the earthworms in water before returning them to the soil.

Note: About 10 earthworms per square foot of soil are generally considered a good population. Populations generally do not exceed 20 per square foot of soil generally.

Note: the action of microorganisms (breaking down plant and animal residues and creating soil organic matter and humus as a binding material).

# Soil Physical Observations and Estimations.

Full Description of the procedure is at: http://soils.usda.gov/sqi/assessment/files/chpt11.pdf

**Simplified version of procedure:**

1. Dig a hole about 1 foot deep and 1 foot wide.

2. Measure the depth of the topsoil. Look for color changes from the soil surface downward through the soil pit face.
   - Record the darker surface layer.

3. Take a look at the roots in the hole.
   - The roots should be well branched with lots of fine root hairs.
   - Look for restrictive layers, the roots will tell you.

4. Feel for restrictive layers, with metal rod.
   - Feel for the resistance as you push the rod into the soil.

A penetrometer can also be used, it measures PSI.

5. Look at the soil structure and measure in the different layers. Soil structure affects the retention and transmission of water and air in the soil as well as the mechanical properties of the soil. Observing and describing soil structure in the field is subjective and qualitative.
   - Record the type, size and grade of the structural aggregates for each layer.
   - Type: Granular, Blocky, Platy, Single grain, or Massive.
   - Size: Platy or Blocky - Fine, medium or thick.

Soil processes involved in the development of soil structure are as follows (Rowell, 1994):
· Drying and wetting, which cause shrinking and swelling, creating cracks and channels;
· Freezing and thawing, which creates spaces as ice is formed;
· The action of roots (removal of water, release of exudates (organic materials), and formation of root channels);
· The action of soil animals (moving soil material around, creating burrows, and bringing soil

**Figure 4.** General position of soil compaction zones in cultivated systems (Bennie, 1996)

CULTIVATED LAYER (9 inches) Zone 1 through 4:

Zone 1: Surface crusting, which may impede seedling emergence and water infiltration.
Zone 2: Low impedance zone for roots; loosened by tillage.

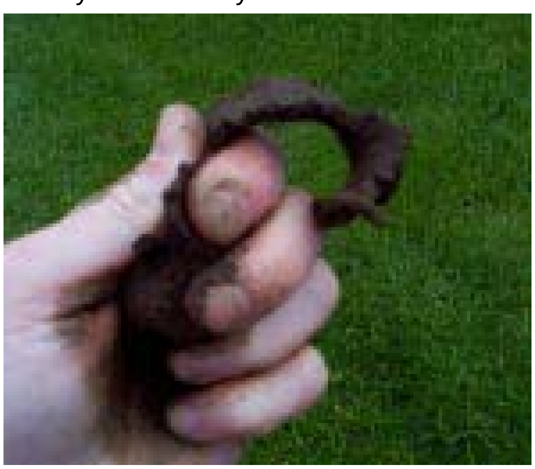
Zone 3: Plowed or deeply loosened cultivated soil that has been re-compacted by vehicular traffic.
LOWEST LAYER OF THE PROWLAYER (10 TO 14 inches) ZONE 4
Zone 4: Subsoil compaction by wheel traffic and tillage implement-soil interactions during tillage.

SUBSOIL LAYER (15 inches plus) ZONE 5
Zone 5: May contain high mechanical impedance due to inherent actors, such as duripans, fragipans, ortstein layers, petrocalcic layers etc. which may occur near the surface if topsoil is not present.

Penetration resistance depends strongly on the soil water content: the dryer the soil, the greater the resistance to penetration. Therefore, the water content of the soil should be noted when taking a measurement. Penetration resistance is best determined when the soil is at field capacity, which is a uniform condition that can be reproduced from season to season.

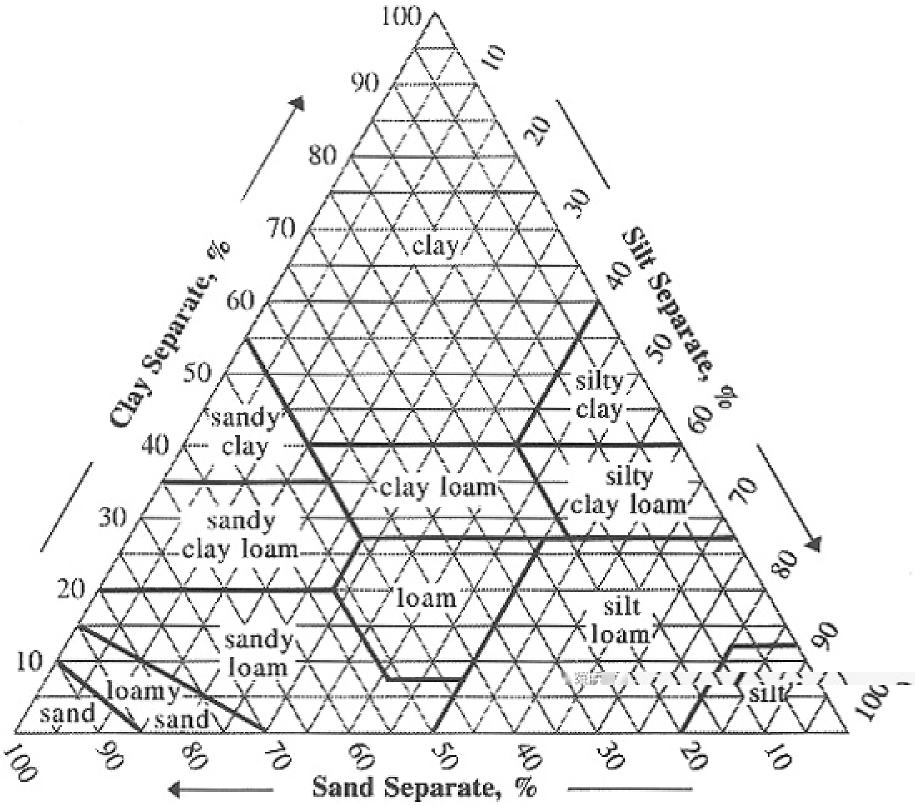
6. Texture can be determined by feel. Place approximately ¼ cup of soil in palm. Add water drop wise and knead the soil to break down all aggregates. Soil is at the proper consistency when plastic and moldable, like moist putty.

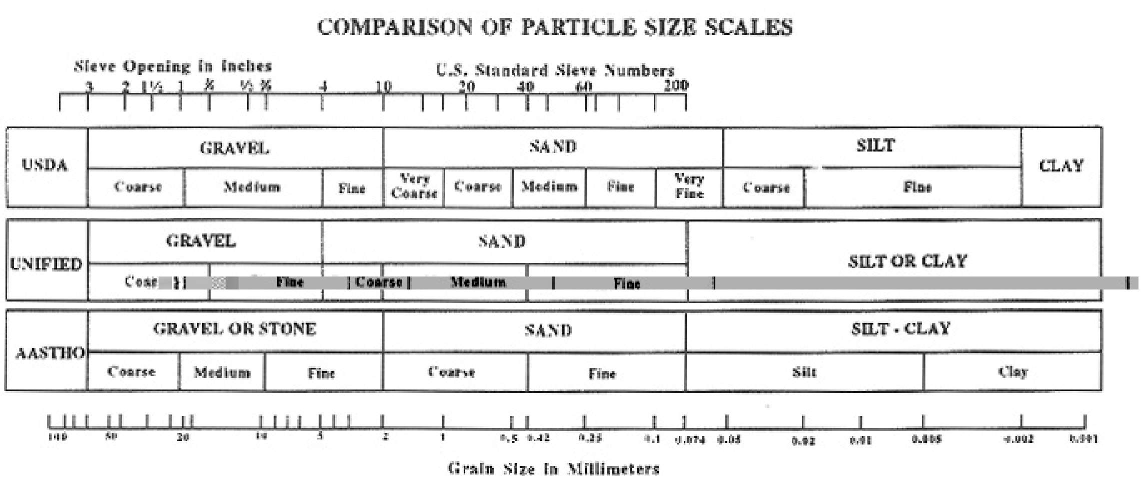
- Sand - feels gritty. - 2.0 mm (very coarse) to .05 mm (very fine);
- Silt - feels smooth like baby powder or foot powder. - .05 mm to .002 mm;
- Clay – feels sticky. - Smaller than .002 mm.



***Twelve Soil Textural Classes.*** Definitions of the 12 textural classes are based on the relative proportion, or weight, of these three particle classifications. Sandy soil, for example, has a greater proportion of sand particles than silt or clay. In reading the textural triangle (Figure 5), any two particle size percentages will locate the textural class. For example, a soil containing 20% clay and 40% sand is located in the *loam* textural class (Figure 5).

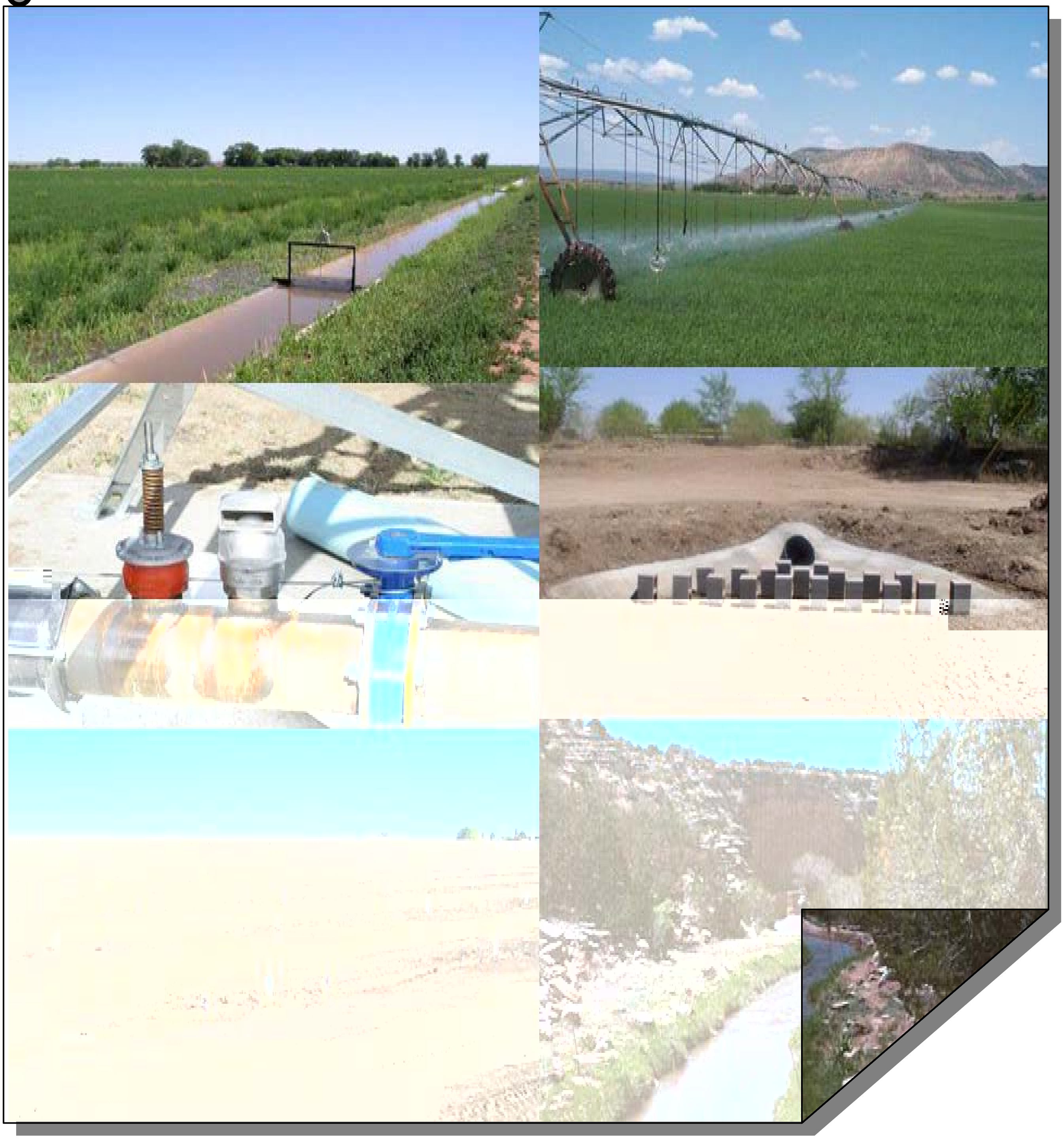
USDA Soil Texture Triangle.



# Station 4 - Irrigation Water Management

## NM Integrated Water Management Handbook



IWM – 1. - Planning for Irrigation Water Management

The Natural Resources Conservation Service provides technical assistance in planning and designing irrigation systems with landowners. This planning process includes the following steps:

1. Identify resources of concern,
2. Determine irrigator objectives,
3. Inventory resources,
4. Analyze resource data,
5. Formulate irrigation alternatives,
6. Evaluate alternatives,
7. Document decisions,
8. Water user implements irrigation plan,
9. Follow-up.

## CONSIDERATIONS FOR PLANNING AN IRRIGATION SYSTEM

Some of the major items to consider in planning an on-farm irrigation system are:

- Water Quantity Available – How much water is available for irrigation and when is it available?
- Water Quantity Needed – Is there adequate water available to meet the demand of the crops to be grown while considering the irrigation efficiency?
- Water Quality – Is the salinity, pH and mineral content of the water compatible with the planned crops and irrigation method?
- Irrigation Method – Is the proposed irrigation method compatible for the crop to be grown?
- Soil Type – Is the proposed irrigation method compatible with the soil type, in terms of infiltration rate, water holding capacity, and stratification that may exist in the soil profile?
- Opportunities/Strategies for Saving Water – community/watershed meetings, action plans – see example this section

On lands used primarily for field and forage crop production, orchards, and ornamental crops, the producer's inputs and management practices may have a significant impact on the current and future conditions of Soil, Water, Air, Plant, Animal and Human (SWAPA + H). As well as soils, rainfall and other natural resource information, cropland inventory needs to include a description of current crops, crop rotations, tillage operations, nutrient and pest management inputs, livestock numbers and class, available equipment, and the timing and management of other important activities. The best source for this information is the client and is best collected when the client and the planner work together on-site in the planning area (field, tract or farm). The overall Cropland Inventory Worksheets (Agronomy Tech Note 70, http://www.nm.nrcs.usda.gov/technical/tech-notes/agro/ag70.doc) and the IWM Inventory (in the following section) can be used.

Linda Scheffe, 2008